Volume 35 JULY, 1961 Number 4

JOURNAL OF PALEONTOLOGY

A publication of The Society of Economic Paleontologists and Mineralogists *and* The Paleontological Society *with the generous support and cooperation* of The American Association of Petroleum Geologists *and* The Geological Society of America

CONTENTS

Eugonophyllum, a new Pennsylvanian and Permian algal genus ..... *Kenji Konishi* and *John L. Wray* 659

An extinct conifer, *Larix* (?) *pleistocenicum*, n. sp., from Yarmouth interglacial deposits of Indiana ..... *H. O. Beals* and *W. N. Melhorn* 667

The Permian ammonoids of Australia ..... *Brian F. Glenister* and *W. M. Furnish* 673

The ammonite family Binneyitidae Reeside in the Western Interior of the United States ..... *W. A. Cobban* 737

Upper Devonian conodonts from Bighorn Mountains, Wyoming ..... *R. L. Ethington, W. M. Furnish* and *J. R. Wingert* 759

Jackson Eocene Ostracoda from the Cocoa Sand of Alabama ..... *Paul R. Krutak* 769

The Silurian Eurypterida of the Welsh Borderland ..... *Erik N. Kjellesvig-Waering* 789

Paleolimnnlogy: Part 2—Harvey and Sedgwick Counties, Kansas: stratigraphy and biota ..... *Paul Tasch* 836

PALEONTOLOGICAL NOTES

Correlation with Great Britain of Glen Dean crinoid fauna (Chester, Mississippian) from Illinois Basin ..... *Alan S. Horowitz* and *T. G. Perry* 866

The type of *Pentremites* Say ..... *Robert O. Fay* 868

Note on the preparation of samples for discoasterids ..... *William W. Hay* 873

An occurrence of *Archimedes* in southern Nevada ..... *N. Gary Lane* 874

The magnetic separator as a tool in micropaleontology ..... *R. Eckert, W. W. Hay, G. Lorenz* and *P. Vogt* 876

Conodonts from the eastern flank of the central part of the Big Horn Mountains, Wyoming ..... *Frank L. Koucky, Norbert E. Cygan* and *Frank H. T. Rhodes* 877

(Continued on back cover)

EDITORS

For The Paleontological Society: ERWIN C. STUMM, Museum of Paleontology, University of Michigan, Ann Arbor, Michigan.

For The Society of Economic Paleontologists and Mineralogists: M. L. THOMPSON and CHARLES COLLINSON, Illinois State Geological Survey, Urbana, Illinois.

THE JOURNAL OF PALEONTOLOGY is published bimonthly. The issues for January, May, and September are sponsored by The Paleontological Society in cooperation with The Geological Society of America; those for March, July, and November are sponsored by The Society of Economic Paleontologists and Mineralogists in cooperation with The American Association of Petroleum Geologists.

The subscription price for the JOURNAL is $15.00 per year prepaid to addresses in the United States. Postage is charged extra for all other countries in the Postal Union, 40 cents on annual subscriptions (total $15.40). Single numbers $3.00 each to nonmembers, $1.75 to members.

Communications about the JOURNAL, advertising, subscriptions, rates, change of address, and nonreceipt of preceding numbers, should be addressed to The Society of Economic Paleontologists and Mineralogists, P. O. Box 979, Tulsa 1, Oklahoma. Claims for nonreceipt of preceding numbers must be submitted within three months of the date of publication in order to be filled gratis. Communications about membership and requests for blanks for nomination of new members should be directed to the secretary of the respective society.

Authors should consult a recent issue of the JOURNAL for appropriate style and form before preparing their manuscripts. A brief informative abstract should accompany every article, except paleontological notes, nomenclatural notes, or short papers in which the title is sufficient to serve as an abstract of the contents. All new taxonomic names proposed in a paper should appear in the abstract.

Contributors are requested to instruct their photographers to illuminate fossils from the upper left side, the conventional manner. Plates normally should be arranged for publication at the maximum size of $5\frac{1}{2} \times 8\frac{1}{2}$ inches, exclusive of margins and heading. Text-figures should be designed for reproduction at either single column ($2\frac{1}{2}$ inches) or full page ($5\frac{1}{2}$ inches) width, maximum height $7\frac{1}{2}$ inches. Typewritten copy is not acceptable for text-figures.

OFFICERS OF THE SOCIETIES

THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

For the year ending March 1962

President
L. L. SLOSS, Evanston, Illinois

Past-President
WILLIAM M. FURNISH, Iowa City, Iowa

Vice-President
KENNETH E. LOHMAN, Washington, D. C.

Secretary-Treasurer
LLOYD C. PRAY, Littleton, Colorado

Councilors
LYMAN D. TOULMIN, Tallahassee, Florida
for Paleontology
ALBERT L. KIDWELL, Tulsa, Oklahoma
for Mineralogy

Editors
M. L. THOMPSON and CHARLES COLLINSON
Urbana, Illinois
for Paleontology
LEWIS M. CLINE, Madison, Wisconsin
for Mineralogy

THE PALEONTOLOGICAL SOCIETY

For the year ending November 1961

President
NORMAN D. NEWELL, New York, N. Y,

Vice-President
SIEMON W. MULLER, Stanford, Calif.

Secretary
HARRY B. WHITTINGTON, Cambridge, Mass.

Treasurer
CLAUDE C. ALBRITTON, Dallas, Texas

Editors
ERWIN C. STUMM, Ann Arbor, Mich.
ROBERT V. KESLING, Ann Arbor, Mich,

Past-Presidents
KENNETH E. CASTER, Cincinnati, Ohio
FRANK M. SWARTZ, University Park, Pa.
ARTHUR K. MILLER, Iowa City, Iowa

Second-class postage paid at the Post Office at TULSA, OKLAHOMA, and an additional mailing office, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in paragraph 4, section 538, P. L. and R., authorized April 3, 1935.

Printed in U. S. A.

GEORGE BANTA COMPANY, INC., MENASHA, WISCONSIN

JOURNAL OF PALEONTOLOGY

A publication of THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS *and* THE PALEONTOLOGICAL SOCIETY *with the generous support and cooperation of* THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS *and* THE GEOLOGICAL SOCIETY OF AMERICA

VOLUME 35 JULY, 1961 NUMBER 4

EUGONOPHYLLUM, A NEW PENNSYLVANIAN AND PERMIAN ALGAL GENUS

KENJI KONISHI AND JOHN L. WRAY

Kanazawa Univ., Japan, and The Ohio Oil Company, Littleton, Colorado

ABSTRACT—A new genus of calcareous algae, *Eugonophyllum*, based on the type species *E. johnsonii*, n. sp., from rocks of Virgil age (Upper Pennsylvanian) in New Mexico, resembles *Anchicodium* Johnson and *Ivanovia* Khvorova, but differs in having the cortex differentiated into an inner and outer layer. The inner cortex (subcortex) of the new genus is composed of prominent anastomosing utricles extending parallel to the surface of the blade. A second species, *E. huecoense*, n. sp., is described from Wolfcamp rocks (Lower Permian) in New Mexico. *Anchicodium magnum* Endo is referred to this new genus. The blade-shaped thallus of *Eugonophyllum* had an erect growth habit. Perforations in the thallus and presumed reproductive organs are found in *Eugonophyllum* but are unknown in *Anchicodium* and *Ivanovia*. This new genus is interpreted as having generally inhabited the inner sublittoral environment at a depth below normal wave agitation. *Eugonophyllum* and the related codiacean genera, *Anchicodium* and *Ivanovia*, are important world-wide contributors to both biohermal and non-biohermal carbonate facies of Pennsylvanian and early Permian age.

INTRODUCTION

IN THE process of making a detailed petrographic and paleontologic study of Virgil age (Upper Pennsylvanian) bioherms and associated strata in the Sacramento Mountains of New Mexico (Wray, 1959), it became apparent that the dominant biotic constituent of the bioherms is plate-shaped fragments of blady calcareous algae. These algal remains are often poorly preserved on account of extensive recrystallization of the limestones, but the morphologic features of these algae most closely resemble the characters of the genera *Anchicodium* Johnson, 1946, and *Ivanovia* Khvorova, 1946. During the course of this investigation, however, the discovery of locally well preserved algae in these Virgil age limestones reveal morphologic features that differ sufficiently from *Anchicodium* and *Ivanovia* to warrant the establishment of a new genus, *Eugonophyllum*. Subsequently, algae belonging to this new genus were found in lower Permian limestones of south-central New Mexico, Pennsylvanian strata in northern New Mexico, Texas, and Kansas, and the Permo-Carboniferous of Austria and Japan.

These three codiacean genera, *Anchicodium*, *Ivanovia*, and *Eugonophyllum*, are now recognized as being important world-wide contributors to both biohermal and non-biohermal carbonate facies of Pennsyl-

vanian and early Permian age. The widespread occurrence of these late Paleozoic algae in the United States has been cited recently by Parks (1958) and Wray (1959).

Types and figured specimens are in the U. S. Geological Survey Algal Collection, Denver Federal Center, Denver, Colorado.

The authors are grateful to J. Harlan Johnson of the Colorado School of Mines for supplying primary types from his original collection of *Anchicodium* for examination. G. Arthur Cooper of the United States National Museum kindly made available collections under his care. Lloyd C. Pray and Alan S. Horowitz of the Denver Research Center of The Ohio Oil Company assisted in field work and have been helpful in discussion and manuscript review.

Publication of this manuscript is authorized by the Director, U. S. Geological Survey and The Ohio Oil Company.

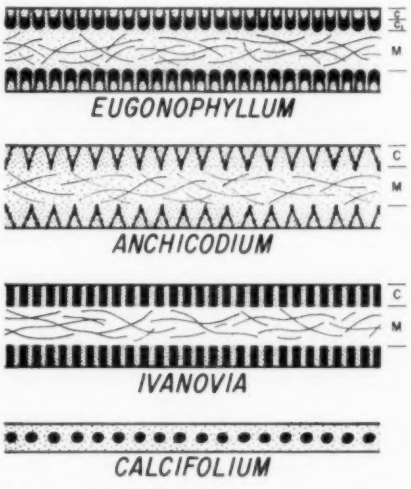
SYSTEMATIC DESCRIPTIONS

Phylum CHLOROPHYCOPHYTA
Papenfuss, 1946
Class CHLOROPHYCEAE Kützing, 1843
Order SIPHONALES Wille *in* Warming, 1884 orth. mut.
Blackman & Tansley, 1902
Family CODIACEAE (Trevisan)
Zanardini, 1843
Genus EUGONOPHYLLUM Konishi & Wray, n. gen.

Type species.—*Eugonophyllum johnsonii* Konishi & Wray, n. sp.

Diagnosis.—Thallus calcified with broad, undulating blades perforated sporadically. Perforations circular to elliptical in shape, variable in size, and margin revolute toward either side of blade. Sessile, probably stipitate, standing vertically against substratum. Blade pseudoparenchymatous, consisting of cortex (differentiated into an inner and outer layer) and medulla. Medulla composed of filaments extending parallel to the surface of blade and dichotomizing as well as interweaving. Inner cortex (subcortex) composed of prominent layer of anastomosing utricles extending parallel to the surface. Outer cortex thin and generally recrystallized, consisting of fine branchlets given off perpendicularly from the subcortical utricles. Reproductive organ borne within a subcortical protuberance in the blade, spherical in shape, and scattered irregularly over the surface of the blade

Remarks.—The differentiation of the cortex into an inner (subcortex) and an outer layer is a distinctive feature of *Eugonophyllum* (Text-fig. 1). The subcortex is composed of a system of anastomosing utricles which parallel the surface of the blade and appear circular in cross section. The thin outer cortex of the new genus is generally recrystallized, but occasionally fine branchlets extending from the subcortical utricles may be observed penetrating the outermost calcified wall. A similar feature in fossil Codiaceae has been observed by Høeg (1927, p. 5) in the Ordovician genus *Dimorphosiphon* and by Endo (1951, p. 127) in *Hikorocodium*. The medullary filaments in *Eugonophyllum* may be preserved as thick tubes similar to those of *Dimorphosiphon* or *Halimeda*, or as thin threads like those of *Succodium* Konishi, 1954, or the Permian chaetangiacean genus *Gymnocodium*.

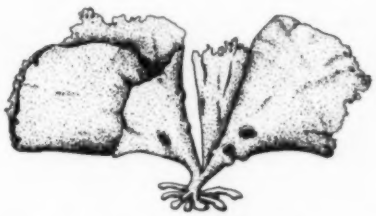


TEXT-FIG. 1—Schematic diagram illustrating wall structure as seen in transverse sections of blady upper Paleozoic Codiaceae. ×25. Utricles are shown in solid black. Degree of calcification is indicated by intensity of stippled pattern. C=cortex; c=outer cortex; c_1=subcortex; M=medulla.

Anchicodium and *Ivanovia* are closely related to *Eugonophyllum*. Johnson (1946, p. 1098) described the major part of the thallus of *Anchicodium* as being an essentially cylindrical growth development and compared it with *Gymnocodium* and the Recent genus *Codium* on the basis of similar structural features and growth habit. Endo (1951, p. 125) supported these comparisons in his descriptions of Japanese species of *Anchicodium*. An examination of topotype specimens of *Anchicodium* from Kansas indicates that the thallus has a bladelike habit similar to *Eugonophyllum*. However, perforations in the thallus or reproductive organs have not been observed in *Anchicodium*. The cortical structure of *Anchicodium* is not differentiated into two layers as in *Eugonophyllum*, but is composed of a single layer made up of alternately constricted utricles extending perpendicularly or obliquely from the medullary filaments, and therefore more or less normal to the surface of the blade (Text-fig. 1).

Ivanovia Khvorova, 1946, resembles *Eugonophyllum* and *Anchicodium* in growth form and blade structure. This monotypic genus based on *I. tenuissima* from the Middle Carboniferous of the Moscow Basin is recognized in limestones of Des Moines age in southeastern Utah. According to Khvorova (1946, p. 737), *Ivanovia* is characterized by an "outer cover [=cortex] . . . formed of cylindrical cells [=utricles] . . . arranged perpendicular to the surface of the thallus." This simple pillarlike structure of the cortical utricles suggests a less advanced structure compared with that of either *Anchicodium* or *Eugonophyllum* (Text-fig. 1). Neither perforations in the thallus nor reproductive organs have been found in *Ivanovia*. This genus was originally placed in either the Rhodophyceae or Phaeophyceae by Khvorova (1946, p. 737) but more recently in the Siphonales by Maslov (1956, p. 84).

A Viséan-Namurian alga, *Calcifolium* Shvetzov & Birina, 1935, (Maslov, 1956, p. 47; Johnson, G. A. L., 1958, p. 147) has a growth form similar to *Eugonophyllum*, *Anchicodium*, and *Ivanovia* but the internal structure of the blade is monostromatic (Text-fig. 1). This Carboniferous genus is placed in the Codiaceae by Maslov (1956, p. 47) and G. A. L. Johnson (1958, p. 153).



TEXT-FIG. 2—Growth habit of Recent Phaeophycea, *Thalassiophyllum clathrus* (Gmelin) Postels & Ruprecht. Natural size. (From Setchell, 1905.)

A phylogenetic series appears to exist between *Calcifolium*, *Ivanovia*, *Anchicodium*, and *Eugonophyllum*. The linkage starts with *Calcifolium* which has a monostromatic blade consisting of dichotomously branching filaments. The next stage may be seen in *Ivanovia*, which, as a result of corticulation, has a thick medulla and a thin cortex characterized by a simple pillarlike structure. *Anchicodium* is characterized by a more complex cortical structure consisting of constricted and ramifying utricles. *Eugonophyllum* has the most advanced structure with the cortex differentiated into an inner and outer layer. This differentiation of the cortex, an apparently more complex growth habit of the thallus including perforations, and the occurrence of reproductive organs characterize the new genus. The distinction, however, between these genera may become obscure when the internal structure is obliterated by recrystallization.

Among Recent algal genera, bladelike growth forms similar to that interpreted for *Eugonophyllum* may be found in the Chlorophyceae and Phaeophyceae. The chlorophycean genera, *Ulva* and *Udotea*, suggest a growth habit similar to that of *Eugonophyllum;* however, the internal structure of the blade is more complex in the fossil genus and the thallus of these Recent genera is neither heavily calcified nor perforated. The growth form of some Phaeophyceae,e.g., *Thalassiophyllum clathrus* (Gmelin) Postels & Ruprecht (Text-fig. 2), may closely resemble that of *Eugonophyllum*, although the Recent forms are not lime secreting.

The presumed reproductive organs found in *Eugonophyllum* are not clearly understood. Although these organs are a distinctive character of the genus, it can not be determined whether they are gametangia, oögonia, or conceptacles of oögonia or antheridia. The organs closely resemble the conceptacles of the Fucales (Phaeophyceae) in shape, size, and position, but the vegetative structures of *Eugonophyllum* and the Fucales are very different. Among the Recent Siphonales, all the families except the Dichotomosiphonaceae are anisogamous with either a monoecious or dioecious type of reproduction. In the Recent Codiaceae, the complete life history is known only in *Codium* and *Halimeda*. The size of the reproductive organs in *Eugonophyllum*, which is referred to the Codiaceae, is within the range of the gametangia of *Codium* and *Halimeda*. The gametangia of *Halimeda* are uncalcified outgrowths from the surface of the thallus, whereas those of *Codium* are outgrowths from the utricles and remain within the cortex. In this respect, *Codium* resembles *Eugonophyllum*. However, the size of the gametangia is always smaller than the diameter of the utricles in *Codium*, which is just the reverse in the case of *Eugonophyllum*.

Parasitic growths peculiar to *Eugonophyllum*, similar to the "nests of infesting fungal spores" described by Stopes (1910, p. 165), may provide a possible, though improbable, explanation for these organs.

Eugonophyllum is known from Pennsylvanian strata in New Mexico, Texas, and Kansas, the lower Permian in New Mexico, and the Permo-Carboniferous in Austria and Japan.

The name of this genus is derived from the Greek εὔγονος ("productive, fruitful, endowed with generative power") referring to the occurrence of presumed reproductive organs, and φύλλον, n. ("a leaf"), the characteristic form of the thallus.

EUGONOPHYLLUM JOHNSONII Konishi & Wray, n. sp.
Pl. 75, figs. 4,5,7–18

Description.—Thallus consisting of calcified undulating blades several centimeters in length and width, 200 to 700μ thick, perforated sporadically; perforations circular, 1 mm. or more in diameter. Blade consists of (1) medulla composed of filaments 20 to 40μ in diameter, though usually recrystallized into calcite mosaic; (2) subcortex composed of prominent layer of anastomosing utricles, 40 to 50μ in diameter, extending parallel to the surface; and (3) thin, usually recrystallized outer cortex. Reproductive organ spheroidal in shape, 150 to 220μ in diameter, borne within subconical protuberance, becoming papillary at maturity and opening as an ostiole, 60 to 80μ in diameter. Reproductive organs scattered over surface and may occur at edge of blade.

Remarks.—*E. johnsonii* differs from *E. magnum* (Endo) in the smaller size of the subcortical utricles. This species is named for J. Harlan Johnson.

Occurrence.—The type locality is U.S.G.S. Paleobotany Loc. D978, Holder formation (Pray, 1961, p. 87) (Upper Pennsylvanian), Otero County, New Mexico (SE/4 sec. 2, T. 16 S., R. 10 E.), type material collected by Lloyd C. Pray and John L. Wray in 1958. Also from U.S.G.S. Paleobotany Loc. D987, Upper Pennsylvanian, ¼ mile north of Vinton Canyon, El Paso County, Texas, collected by R. L. Harbour and E. L. Yochelson in 1956; U.S.G.S. Paleobotany Loc. D568, Ozawkie member of Deer Creek limestone (Moore, 1949, p. 156) (Virgil), Doniphan County, Kansas (NW cor. sec. 28, T. 4 S., R. 21 E.), collected by J. Harlan Johnson in 1940; U.S.G.S. Paleobotany Loc. D989, gray limestone member of Madera limestone (Pennsylvanian), quarry near Montezuma, San Miguel County, New Mexico (T. 16 N., R. 16 E.), collected by Alan S. Horowitz in 1958; and U.S.G.S. Paleobotany Loc. D990, Upper Pennsylvanian, The Ohio Oil Company No. 2 Hays, depth 6632′, NW/4 sec. 249, blk. 97, Houston and Texas Central survey, Scurry County, Texas.

Holotype.—U.S.G.S. a835b.

Paratypes.—U.S.G.S. a830, a831a, a831b, a832, a833, a834a, a834b, a835a.

Figured specimens.—U.S.G.S. a837, a838, a839, a840.

EUGONOPHYLLUM HUECOENSE Konishi & Wray, n. sp.
Pl. 75, figs. 1–3

Description.—Thallus consisting of undu-

lating blades, 500 to 1250μ thick, perforated sporadically. Perforations circular to elliptical, 1 to 10 mm. in diameter, margins of larger perforations revolute toward either side of blade. Blade consists of central medulla bounded by cortex. Probable reproductive organs occur as spheroidal protuberances, 200 to 350μ in diameter, scattered over surface of blade.

Remarks.—The specimens referred to this new species were obtained from G. Arthur Cooper, United States National Museum, and are all silicified forms recovered by acid etching from the Hueco limestone (Wolfcamp) of New Mexico. The growth habit of this alga is excellently shown by these specimens but the internal structure of the blade is not well preserved. This species is distinguished from *E. johnsonii* by its thicker blades.

Occurrence.—The holotype is from U.S.G.S. Paleobotany Loc. D986, Hueco limestone (Wolfcamp), Otero County, New Mexico (SE/4 sec. 8, T. 22 S., R. 10 E.). Also from U.S.G.S. Paleobotany Loc. D985, Hueco limestone (Wolfcamp), Otero County, New Mexico (sec. 24, T. 23 S., R. 8 E.).

Holotype.—U.S.G.S. a827.

Paratypes.—U.S.G.S. a828, a829.

EUGONOPHYLLUM MAGNUM (Endo)
Pl. 75, fig. 6

Anchiocodium magnum ENDO, 1951, p. 125–126, pl. 11, figs. 3–5; ——, 1952, p. 247, pl. 23, figs. 6, 7; ——, 1954, p. 218, pl. 19, fig. 4; ——, 1957, p. 292–293, pl. 41, fig. 4, pl. 42, fig.2; —— & Horiguchi, 1957, p. 175–176, pl. 15, fig. 3.

This species was originally described as having a cylindrical thallus; however, an examination of topotypes and other specimens from various localities of the Middle Pennsylvanian and Lower Permian of Japan indicate a blady habit. The specimens examined fall within the range of dimensions for this species as given by Endo (1951, 1952, 1954, 1957) and Endo & Horiguchi (1957).

Thickness of figured blade fragment, 400μ; diameter of utricles, 85μ; dimensions of a probable reproductive organ, 225μ $\times$ 385μ. The greater diameter of the cortical utricles distinguishes this species from *E. johnsonii*.

Occurrence.—This species has been reported by Endo from Middle Pennsylvanian and Lower Permian limestones in the Japanese islands. The figured specimen is from U.S.G.S. Paleobotany Loc. 991, *Fusulina* zone of Yayamadake limestone (Middle Pennsylvanian), eastern slope of Mt. Yayamadake, Kuriki-mura, Yatsushiro-gun, Kumamoto Prefecture, Kyushu, Japan.

Figured specimen.—U.S.G.S. a836.

ENVIRONMENTAL INTERPRETATIONS

Eugonophyllum has been found most commonly in clastic carbonate rocks (calcarenites and calcirudites) composed largely of fossil debris. The interstitial material consists of varying amounts of clear calcite cement and lime mud. The fossil constituents associated with *Eugonophyllum* are fusulinids, small foraminifers (commonly ophthalmidids), echinodermal debris, brachiopod shell fragments, and other calcareous algae (Dasycladaceae and Spongiostromata). *Eugonophyllum* frequently occurs as the dominant biotic constituent and may occur to the exclusion of other fossils.

Eugonophyllum was a rather broad-bladed upright plant as suggested by the perforations in the blades, the bilateral symmetry of the internal structure of the thallus, and the occurrence of reproductive organs on both surfaces of the blades. In growth position it is interpreted as having been at least several inches in height. These broad calcareous blades could not have withstood a high degree of turbulence; for this reason the alga probably inhabited a zone below that of normal wave agitation. In protected waters where wave action was restricted, this alga could have existed at very shallow depths. Perforations in the blades apparently served to reduce the resistance of the erect blades to current action of even a gentle nature. The occasional association of this alga with encrusting types of blue-green algae (Spongiostromata) points to a very shallow water environment, at least locally, of probably less than one fathom. The assumed photic requirements of this alga, based on analogy with Recent calcareous Codiaceae, suggest that it did not commonly live at depths greater than 100 feet. In

short, *Eugonophyllum* inhabited the inner sublittoral environment at a depth below normal wave agitation and possibly extended to depths of 100 feet, but occurred most abundantly in the shallow portion of its depth range.

Many of the bioherms and biostromes of Pennsylvanian and Permian age composed largely of *Eugonophyllum* or related codiacean genera, *Anchicodium* and *Ivanovia*, appear to represent clastic accumulations of fragmented algal blades. However, the Virgil age bioherms in the Sacramento Mountains of New Mexico, in which *Eugonophyllum* occurs as the dominant fossil constituent, are interpreted as having been formed partly through the localization of carbonate sedimentation by erect, leaflike blades of this alga. Ginsburg & Lowenstam (1958, p. 313) have discussed the influence of Recent marine grasses in Florida Bay in trapping and binding fine sediment to form submarine banks, and suggested possible fossil analogues of this mechanism. Patchy growths of *Eugonophyllum* may have produced a baffle which could have effectively reduced the velocity of currents over the sea bottom. This caused fine sediment, mainly lime muds, to be deposited, in addition to the clastic accumulation of algal blades and other biotic constituents. This process gradually produced a build-up above the general level of the sea floor. Much of the fine calcareous sediment may have been produced locally by the algae themselves. The bioherms probably originated as broad, moderately low relief submarine structures, their tops possibly extending up to, but generally occurring below, the zone of vigorous wave agitation.

These Virgil age bioherms in New Mexico do not present convincing evidence that they possessed the characteristics of true reefs with wave resistant qualities as suggested by Plumley & Graves (1953, p. 4). Calcareous blades of *Eugonophyllum* do not appear to have been able to provide the rigid framework necessary to resist intense wave action. Encrusting types of blue-green algae could have served as a binding agent, but these occur only locally and are not distributed in sufficient quantity throughout the bioherms to have acted as a major framework builder.

REFERENCES

Endo, Riuji, 1951, Stratigraphical and paleontological studies of the later Paleozoic calcareous algae in Japan, I: Palaeontological Soc. Japan Trans. and Proc., new ser., no. 4, p. 121–129, pls. 10,11.

——, 1952, Stratigraphical and paleontological studies of the later Paleozoic calcareous algae in Japan, IV: Palaeontological Soc. Japan Trans. and Proc., new ser., no. 8, p. 241–248, pl. 23.

——, 1954, Stratigraphical and paleontological studies of the later Paleozoic calcareous algae in Japan, IX: Saitama Univ., Sci. Repts., ser. B, v. 1, no. 3, p. 217–221, pl. 19.

——, 1957, Stratigraphical and paleontological studies of the later Paleozoic calcareous algae in Japan, XI: Saitama Univ., Sci. Repts., ser. B, v. 2, no. 3, p. 279–305, pls. 37–44.

—— & Horiguchi, Mankichi, 1957, Stratigraphical and paleontological studies of the later Paleozoic calcareous algae in Japan, XII: Japan. Jour. Geology Geography, v. 28, no. 4, p. 169–177, pls. 13–15.

Ginsburg, R. N. & Lowenstam, H. A., 1958, The influence of marine bottom communities on the depositional environment of sediments: Jour. Geology, v. 66, no. 3, p. 310–318.

Høeg, O. A., 1927, *Dimorphosiphon rectangulare;* preliminary note on a new Codiacea from the Ordovician of Norway: Avh. Norsk. Vidensk.-Akad., Oslo, I. Mat.-Nat. Kl., 1927, no. 4, p. 1–15, pls. 1–3.

Johnson, G. A. L., 1958, Biostromes in the Namurian Great Limestone of northern England: Palaeontology, v. 1, pt. 2, p. 147–157, pls. 30,31.

Johnson, J. H., 1946, Lime-secreting algae from the Pennsylvanian and Permian of Kansas: Geol. Soc. America Bull., v. 57, p. 1087–1120, pls. 1–10.

Khvorova, I. V., 1946, On a new genus of algae from the Middle Carboniferous deposits of the Moscow Basin: Acad. Sci. URSS, C. R. (Dokl.), v. 53, no. 8, p. 737–739.

Konishi, Kenji, 1954, *Succodium*, a new codiacean genus, and its algal associates in the late Permian Kuma formation of southern Kyushu, Japan: Jour. Fac. Sci., Univ. Tokyo, sec. II, v. 9, pt. 2, p. 225–240, pls. 1,2.

Maslov, P. B., 1956, Iskopaemye izvestkovye vodorosli SSSR (Calcareous algae of the USSR): Akad. Nauk SSSR, Trud. Inst. Geol. Nauk, no. 160, 301 p., 86 pls.

Moore, R. C., 1949, Divisions of the Pennsylvanian system in Kansas: Kansas Geol. Survey, Bull. 83, p. 1–203.

Parks, J. M., Jr., 1958, Plate-shaped calcareous algae in late Paleozoic rocks of Midcontinent (abs.): Geol. Soc. America Bull., v. 69, p. 1627.

Plumley, W. J. & Graves, R. W., Jr., 1953, Virgilian reefs of the Sacramento Mountains, New Mexico: Jour. Geology, v. 61, no. 1, p. 1–16.

Pray, L. C., 1961, Geology of the Sacramento Mountains Escarpment, Otero County, New

Mexico: New Mexico Bur. Min. & Min. Res., Bull. 35, p. 1–144.

SETCHELL, W. A., 1905, Post-embryonal stages of the Laminariaceae: Univ. Calif. Publ. Bot., v. 2, p. 115–138.

STOPES, M. C., 1910, Ancient plants, being a simple account of the past vegetation of the Earth and of the recent important discoveries made in this realm of nature study: 198 p., London, Blackie & Son, Ltd.

WRAY, J. L., 1959, Origin of some Pennsylvanian algal bioherms in southwestern United States: Guidebook for Joint Field Conference in the Sacramento Mountains of Otero County, New Mexico, Permian Basin Sect. S.E.P.M. and Roswell Geol. Soc., p. 38–39.

(*Explanation of Plate 75 will be found on page 666*)

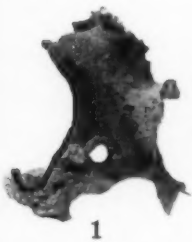
EXPLANATION OF PLATE 75

Figures 1–4 in stereoscopic pairs.

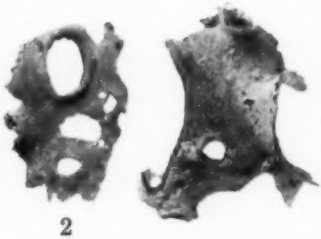
FIGS. *1–3—Eugonophyllum huecoense*, n. sp. *1*, Holotype (USGS a827) Loc. D986, silicified specimen showing performation with revolute margin, ×1; *2*, (USGS a828) Loc. D986, silicified specimen with numerous perforations, ×1; *3*, (USGS a829) Loc. D985, silicified specimen, ×1.

4,5,7–18—Eugonophyllum johnsonii, n. sp. *4*, (USGS a830) Loc. D978, blade fragment showing reproductive organs, ×2; *5*, (USGS a835a) Loc. D978, transverse section of fragment showing reproductive organ at edge of blade, ×10; *7*, (USGS a831a) Loc. D978, transverse section showing cortical utricles, ×20; *8*, (USGS a837) Loc. D987, sections of completely recrystallized blades showing reproductive organs, ×10; *9*, Holotype (USGS a835b) Loc. D978, section through specimen showing reproductive organs and apparent bifurcation as a result of undulating blade, ×5; *10*, (USGS a838) Loc. D568, section of fragment showing reproductive organ and cortical utricles, ×10; *11*, (USGS a839) Loc. D989, section showing reproductive organ and cortical structure, ×10; *12*, (USGS a834a) Loc. D978, section of fragment showing reproductive organs protruding from surface of blade, ×10; *13* (USGS a840) Loc. D990, section of blade showing reproductive organ near top center of fragment, ×10; *14*, (USGS a833) Loc. D978, transverse section through cortical portion of fragment showing utricles extending parallel to surface of blade, ×80; *15*, (USGS a831b) Loc. D978, tangential section through perforations in specimen, ×10; *16*, (USGS a832) Loc. D978, section of blade showing reproductive organs and cortical structure, ×20; *17*, (USGS a834b) Loc. D978, section of sample composed almost exclusively of fragments of this species, ×5; *18*, (USGS a834b) Loc. D978, transverse section of blade showing cortical structure, ×20.

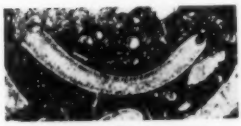
6—Eugonophyllum magnum (Endo) (USGS a836) Loc. D991, section of blade showing cortical structure and probable reproductive organ, ×10.



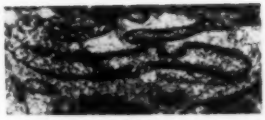
1



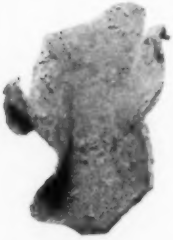
2



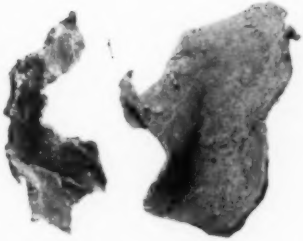
5



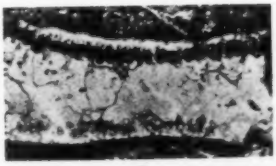
6



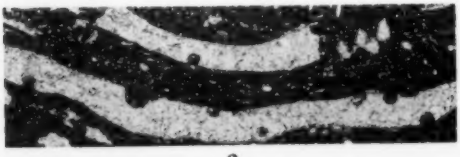
3



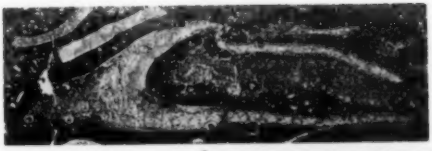
4



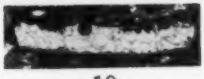
7



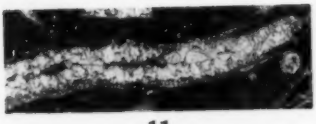
8



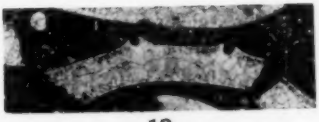
9



10

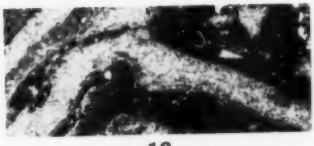


11

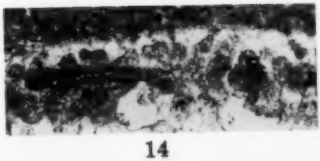


12

15

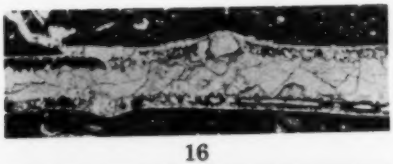


13

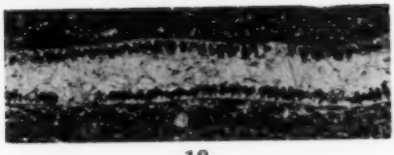


14

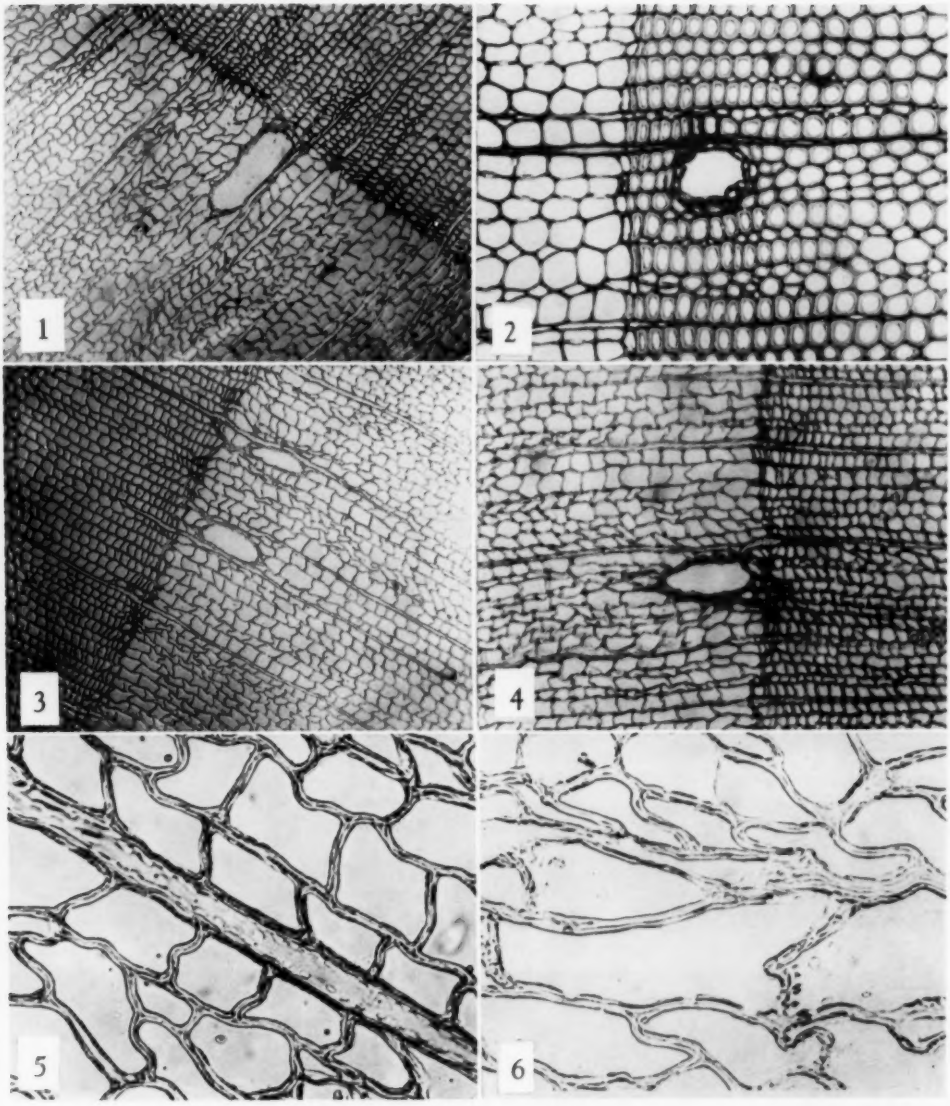
17



16



18


1
2
3
4
5
6

JOURNAL OF PALEONTOLOGY, V. 35, NO. 4, P. 667–672, PLS. 76, 77, 1 TEXT-FIG., JULY, 1961

AN EXTINCT CONIFER, *LARIX* (?) *PLEISTOCENICUM*, N. SP. FROM YARMOUTH INTERGLACIAL DEPOSITS OF INDIANA

H. O. BEALS AND W. N. MELHORN
Purdue University, Lafayette, Indiana

ABSTRACT—During spillway construction at the Brush Creek reservoir near Butlerville, Jennings County, Indiana, Yarmouth interglacial floodplain deposits were exposed in a buried valley. Fragments of wood from the forest bed were first identified as spruce, but careful examination revealed several unusual anatomical features not found in living North American conifers. The wood specimens show resemblance to both *Larix* and *Picea*, but because other features favor *Larix* more closely, the name *Larix* (?) *pleistocenicum* Beals, n. sp. ,is proposed for this Pleistocene coniferous wood.

Few published descriptions of Pleistocene wood are available. Proper preparation and examination of wood specimens is suggested to determine if woody material is of value as a means of correlation of Pleistocene glacial and interglacial deposits.

INTRODUCTION

BRUSH CREEK reservoir is located near Muscatatuck State Training School, in the NE¼ Sec. 16, T. 7 N., R. 9 E., two miles northeast of Butlerville, Jennings County, Indiana. When spillway construction for this reservoir was commenced, a glacially filled bedrock gorge was encountered at the exact place where plans had been made to locate the spillway. Because construction plans required the use of a rock floor, the spillway position was shifted to a new site where it cut through a bedrock spur extending partly across the valley. Excavations at the new spillway site, the original spillway location, and around the margins of the reservoir revealed glacial till deposits of Kansan and Illinoian age and Yarmouth interglacial floodplain deposits containing peat and soil together with many wood fragments.

GLACIAL STRATIGRAPHY

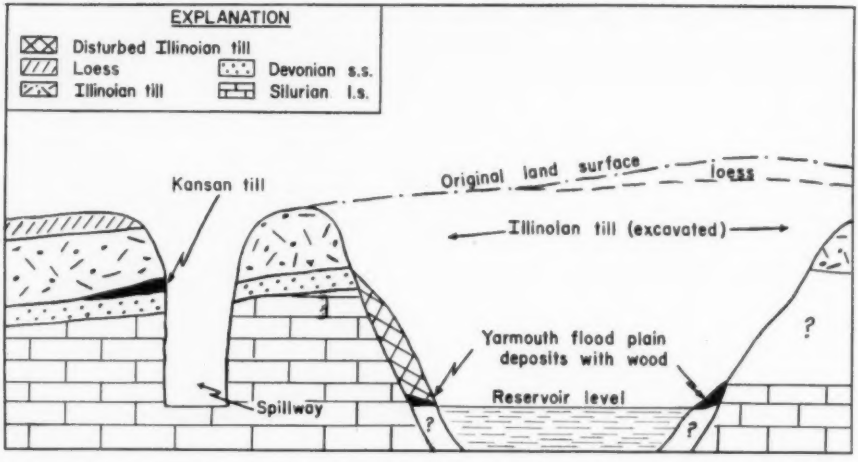
The measured stratigraphic section at Brush Creek reservoir is as follows (Wayne, 1955, p. 32):

		Thickness in feet
Quaternary		
Illinoian		
Clay:	light yellowish brown, mottled, silty, noncalcareous	5.0
Till:	brown, sandy and clayey, noncalcareous	2.0
Till:	gray, brown along joints, sandy, noncalcareous	5.0
Till:	gray, sandy, calcareous throughout, but less calcareous at base; oxidized brown along joints; contains large, randomly oriented chunks of dark yellowish brown noncalcareous till	15.0
Kansan		
Till:	dark yellowish brown to orange, noncalcareous, clayey and somewhat sandy; contains abundant chert pebbles and scattered quartzite pebbles	1.0
	TOTAL	28.0
Devonian		
Sandstone:	calcareous, loosely consolidated (Pendleton sandstone?)	2.8
Silurian		
Limestone:	dolomitic, siliceous nodules, cherty	9.2+

Lacustrine sediments and glacial till fill the former valley. As much as 2 feet of dark gray or greenish gray, noncalcareous, sandy clay which contains rooted stumps and is capped locally by a peaty zone is exposed

EXPLANATION OF PLATE 76

FIG. 1—Transverse section of *L.* (?) *pleistocenicum* showing elongated resin canal. ×100.
2—Transverse section of *L. laricina* K. Koch showing abrupt change from springwood to summerwood and thick-walled epithelial cells in resin canals. ×100.
3—Transverse section of *L.* (?) *pleistocenicum* showing two elongated resin canals. ×100.
4—Transverse section of *L.* (?) *pleistocenicum* showing ovoid resin canal. Note lack of distinct epithelium. ×150.
5—Transverse section of *L.* (?) *pleistocenicum* showing detail of ray cells. ×645.
6—Transverse section of *L.* (?) *pleistocenicum* showing detail of ray in springwood. ×645.



TEXT-FIG. 1—Schematic cross-section of Brush Creek reservoir and spillway showing relation of Pleistocene deposits and *Larix* (?) *pleistocenicum* wood (not to scale).

along the reservoir shore line (Text-fig. 1). The clay and peat are apparently late-Yarmouth-early-Illinoian floodplain deposits over which Illinoian ice later moved. The basal 5–15 feet of overlying dark gray, calcareous till contains abundant wood fragments and masses of soil that were incorporated into debris carried by the ice, moved a short distance, and redeposited (Wayne, 1955, p. 33).

DESCRIPTION OF WOOD

Samples of wood from the forest bed were collected by Dr. Helmut Kohnke, Department of Agronomy, Purdue University during the summer of 1956 and subsequently given to the senior author for identification. The specimens range from pencil size to about 5 inches in diameter and are 15 or more inches in length. The wood is dark brown, very brittle, and exhibits excellent preservation in most of the samples. No silicification had taken place, although some silica particles were present in the outer one-quarter inch of the shell. At least one piece had small pebbles embedded in the surface. Most pieces were curved, probably due to the method of collection of the specimens and not to shearing by glacial ice.

On superficial examination, the wood resembles spruce or larch in the size of tracheids, growth rings, resin canals, and other readily observable features. Growth rings are distinct, although variable in width, and may exhibit collapse of the summerwood. This collapsed tissue commonly appears to be carbonized, although in thin-section it does not show the characteristic black carbon color.

The microscopic anatomy of the wood reveals a number of unusual features, and their arrangement indicates that this conifer was probably different from those living today.

PREPARATION OF MATERIALS

Unstained transverse sections were prepared by an abrasive paper technique developed for wood of this type (Beals & Guard, 1958). The use of "Fabricut," an abrasive cloth mesh, was also employed in preparation of some sections (Beals, 1958). Longitudinal freehand sections were cut, unembedded, with a razor blade wherever possible. In order to observe details of ray crossfields, intertracheid pits, and other features not clearly visible, a cellulose acetate film technique was used (Beals, 1957).

The sections were stained with methylene blue wherever possible, because this stain gave the greatest amount of differentiation of the tissues. Owing to the nature of the wood, no stain or staining technique was found which gave consistently satisfactory

results. In some cases, the presence of infiltrated mineral material (silica) into the cell cavities made observation of certain details difficult.

MICROSCOPIC ANATOMY OF THE WOOD

Transverse surface.—In transverse section, the specimen exhibits distinct growth rings with gradual differentiation from springwood into summerwood (Pl. 76, figs. 1,3,4). The growth rings are narrow, numbering about 30 per inch, and variable in width. The tracheids are thin-walled and show some collapse in the summerwood areas. Where collapse is present the summerwood may become almost structureless, while the springwood and rays appear unaffected. In these collapsed areas, the rays are pushed aside, but can be traced through several rings almost intact. It is presumed that this collapsed condition is a drying defect caused after the specimen has been exposed to the atmosphere, and is not the result of pressure of overlying sediments. It is similar to collapse found in certain modern woods.

Resin canals are found in most rings. Circular canals are interspersed among an unusual oval or radially elongated type of canal (Pl. 76, figs. 1,3,4). All resin canals observed appeared to lack a true epithelium, or if one is present, it has collapsed to form a thick, cell-like structure. This condition is also present in transverse resin canals (Pl. 77, fig. 8).

Diameter of the resin canals ranges from 60 to 75 microns for the circular canals. The elongated canals may reach 130 microns in length. The resin canals usually occur at the beginning of the growth ring, indicating that they may have a traumatic origin. However, no typical traumatic resin canals were observed in any of the sections.

Longitudinal parenchyma is scattered, occurring as individual cells or strands throughout the growth rings (Pl. 77, fig. 1). Strand tracheids are common, especially in the vicinity of the resin canals and in association with parenchyma. One area contained a small group of sclereid-like cells with extremely thick walls.

The rays are, for the most part, uniseriate but may appear biseriate in some springwood areas. The cells are pitted, non-dentate, and tend to be narrower in the summerwood than in the springwood (Pl. 76, figs. 5,6).

The tracheids are small in tangential diameter (20–35 microns), and the summerwood tracheids do not show thick secondary walls as do most modern conifers of this type (compare Pl. 76, figs. 1 and 2). This may be due to selective degradation of the secondary walls of the summerwood tracheids. Intertracheid pits lacking tori can be observed on the radial walls of many tracheids.

Radial surface.—Radial walls of the tracheids are characterized by peculiar large oval bordered pits with a narrow border and large aperture (Pl. 77, figs. 3,4). The pits occur in a single row and show little or no tendency to pair towards the ends of the tracheids. These pits are quite different from normal coniferous bordered pits (compare with Pl. 77, fig. 2), in which the pit border is wide and the aperture narrow.

It is possible that leaching by ground water has altered the pit border and torus, leaving remnants of the pit border and enlarged aperture. However, examination of the pit border (Pl. 77, fig. 4) shows the pit border intact with little evidence of abnormal conditions.

An unusual feature is the apparent lack of crassulae (Bars of Sanio) normally associated with intertracheid pits on the radial walls. If crassulae have been present, all traces have now been removed (Pl. 77, fig. 4).

The rays in some areas are inclined at an oblique angle to the tracheids (Pl. 77, figs. 3,5,6), but this may be due to wavy grain in these areas. It is difficult to determine the composition of the rays but they appear to be composed of both ray parenchyma and ray tracheids. The ray tracheids are not typical (Pl. 77, fig. 6), but appear to be both marginal and included. They are non-dentate, smooth, and non-wavy. They show no evidence of spiral thickening. Both ray tracheids and ray parenchyma are thin-walled.

Typical piciform pitting is not present in the ray crossfields (Pl. 77, fig. 5). The number of pits per ray crossfield varies from two to six (usually two or three) arranged in one or two rows. The pit border is narrow and in many cases appears to be lacking.

Tangential surface.—Simple and fusiform rays are present in the tangential section,

ranging from one to sixteen or more cells in height for both types of rays. In general, most of the rays appear medium high to high.

Included resin canals in the fusiform rays show characteristics similar to those in the transverse section. The epithelial cells appear to be either absent or collapsed. Resin canals are oval to elongate as in the transverse section and the ray is not greatly enlarged in the region of the resin canal.

Bordered pits are present on the tangential walls of the late summerwood tracheids, but are not abundant. These pits are similar to those on the radial walls, but much smaller. The late summerwood tracheids may exhibit spiral checking along the fibrils, but this feature is quite rare. No spiral thickening was observed (Pl. 77, fig. 9).

DISCUSSION OF IDENTIFYING CHARACTERS

Sections of known specimens of spruce, larch, and Douglas fir as well as other members of the Pinaceae were compared with sections of this conifer in an attempt to place it in a recognized genus. While it belongs to the Abietineae of the Pinaceae, and probably in the spruce-larch-Douglas fir complex, it was not possible to assign it positively to any one of these genera.

When the specimen was first examined, it was assigned to *Picea* as an aberrant specimen. However, after considerable study, it was decided that although it had more affinity to *Larix* than to *Picea* it could not be assigned to *Larix* with certainty because of certain peculiar features. A paper was then presented at the American Institute of Biological Sciences meeting at Stanford University in August, 1957, by the senior author and A. T. Guard, expressing the viewpoint that this conifer had a number of unusual features not found in living North American conifers and suggesting that a new genus be created for it. Subsequent study, however, indicates that this conifer should probably be placed in a living genus as an extinct species rather than creating a new genus at this time. Because some doubt remains that *Larix* is the proper genus in which to place this conifer, it will be referred to as *Larix* (?) *pleistocenicum* Beals, n. sp. in this paper.

A major feature used to determine the affinities of a group of conifers is the presence or absence of resin canals in the xylem. Of the native conifers, only *Pinus*, *Larix*, *Picea* and *Pseudotsuga* possess normal resin canals, although traumatic resin canals may occur in other genera. These traumatic canals frequently occur in multiples or very rarely singly in the longitudinal direction. They do not occur as transverse canals.

If it is assumed that the resin canals in *L.* (?) *pleistocenicum* are normal and not traumatic, then the type and number of epithelial cells become important in the separation of genera (Brown *et al.*, 1949). Thin-walled cells occur only in *Pinus*, whereas thick-walled cells occur in the other three genera. Typical thick-walled epithelial cells of *Larix* are shown in Plate 76, figure 2.

In the transverse resin canals, the typical number of epithelial cells as seen in tangential section is 4–6 in *Pseudotsuga*, 7–9 in *Picea*, and 9–12 in *Larix*. The general shape of resin canals tends to be more oval in *Larix* than in the other two genera (Greguss, 1955). As viewed in tangential section, fusiform rays are generally shorter in *Picea* and *Pseudotsuga* and without the long tapered ends commonly seen in *Larix* (Jane, 1950), although these do occur in the other genera.

In comparing the transverse resin canals of *Larix* sp. and *L.* (?) *pleistocenicum* (Pl. 77, figs. 8,9), it will be noted that resin canals in *Larix* sp. are larger than in *L.* (?) *pleistocenicum*, and the ray enlarges around the canal in *Larix* sp. but not in *L.* (?) *pleistocenicum*.

It is possible that collapse of the tissue of the epithelial cells surrounding the resin canals has produced the structureless feature observed. This is unlikely because epithelial cells are usually not subject to collapse even though surrounding tissue, especially summerwood, collapses and becomes structureless. It appears that only thick-walled cells are subject to collapse; rays, thin-walled parenchyma, thin-walled tracheids, and resin canals appear almost always intact.

Spiral thickening in the tracheids of *Pseudotsuga* is a distinctive feature, also shared by the Taxaceae, and in most cases can be used for positive identification of this genus, although this evidence is not infallible. No spiral thickening is present in the specimen of *L.* (?) *pleistocenicum* although spiral thickening may occur in *Larix* and *Picea*. *L.* (?) *pleistocenicum* does not exhibit any

other features that would make it appear to belong to *Pseudotsuga*.

In radial section, dentate and wavy ray tracheids are more frequent in *Larix* and occur more nearly straight and smooth in *Picea*. They are smooth and straight in *L.* (?) *pleistocenicum*. In the *Picea-Larix-Pseudotsuga* complex, pitting in the crossfields is of a type known as "piciform," and occurs primarily in these three native genera, although it is known in others not native to North America. Typical piciform pitting does not occur in *L.* (?) *pleistocenicum*. Pitting in the crossfields is scattered in both *L.* (?) *pleistocenicum* and *Larix* sp., but tends to be located in the corners of the crossfields of *Picea*.

The unusual appearance of the intertracheid pits on the radial walls of *L.* (?) *pleistocenicum* is not found in any living conifer. However, as pointed out previously, this may result from leaching by ground water, microörganisms, or by other factors of degradation. All pits observed appear to have this same characteristic shape, even in strand tracheids (Pl. 77, fig. 1) and on tangential walls. Under polarized light these pits lack the typical "cross" exhibited by all other normal coniferous pits. This may be caused by selective degradation of the secondary wall, but it does not explain the lack of a torus or the characteristic oval shape of the pits. There is no evidence of crowding or distortion by external pressures which would cause this appearance.

The relative abundance of parenchyma in *L.* (?) *pleistocenicum* is unusual because parenchyma does not normally occur in *Picea* and only rarely in *Larix* and *Pseudotsuga*. The lack of crassulae may be due to poor development or degradation.

The features shown by *L.* (?) *pleistocenicum* may be no more than atypical expressions caused by abnormal Pleistocene conditions. Although the great majority of these features may be found within the variability of living conifers, their peculiar combination does not easily fit into a living genus.

Bailey (Bailey & Faull, 1934) cautions against the use of wood anatomy for classifying members of the Coniferales as to tribe or generic affiliations because of great variation of elements even in the same plant. In a study of redwood, *Sequoia sempervirens*, he found that some Mesozoic conifers considered to be distinct from living genera could be assigned to *Sequoia* because of arrangement of variable features.

GEOLOGIC IMPLICATIONS

It is probable that many plants became extinct during the Pleistocene, although few extinct forms have been reported. In the Toronto beds a great number of woody plants were identified (Coleman, 1901), many of which are now extinct in that area. A maple, *Acer pleistocenicum* Penhallow, recovered from the Toronto beds and identified by Penhallow (Dawson & Penhallow, 1889, p. 327) is one of the few identified extinct plants from the Pleistocene. In the same paper, specimens of *Taxus* (*Taxus baccata* L.) (?) are reported to have anatomical features somewhat different from modern species (Dawson & Penhallow, 1889, p. 322). It should be pointed out that wood identification by anatomical features is considered reliable by keys made for mature stem wood, and most woods can be identified on this basis to genus or general groups with little difficulty and with a great amount of certainty. Identification to species, on the other hand, may be extremely difficult and at times impossible. Except when wood is exceptionally different from modern species, most Pleistocene woods have been referred to modern species.

It should also be kept in mind that the gymnosperms, especially the conifers, were far more numerous in remote times than they are today, and instead of 47–48 living genera with approximately 500 species, in the past the number of genera may have totaled several hundred, with species numbering in the thousands.

In recent years, identification of Pleistocene wood has been neglected, and even in well known forest beds such as those at Toronto, Canada, and Two Creeks, Wisconsin, as well as in many others, much of the identification has not been properly carried out. In most cases wood fragments have been identified as "probably spruce or larch," or "coniferous wood" and promptly forgotten. Pleistocene wood is extremely difficult to section properly, especially in the transverse direction, and the presence of infiltrated silica makes the use of a microtome knife on some specimens almost impossible. Most wood anatomists will agree that preparation of this material requires much time and effort for adequate sections for microscopic study, and are content to cut free-

hand radial and tangential sections without preparing the transverse section. In many species, adequate identification can be made with only two sections; in others it cannot.

Few published descriptions of Pleistocene wood have appeared in recent years. Those written many years ago are inadequate, and for the most part were based on gross features, many of which are useless in identification of this type of material. Therefore it is urged that specimens identified many years ago be reëxamined more closely, particularly those from the early interglacial deposits.

It is possible that closer examination of wood from glacial and interglacial deposits may shed more light on climatic and ecologic aspects of the Pleistocene. In itself, wood identification cannot be relied upon to date glacial events, but combined with other factors may be as valuable for correlation purposes as the fossil mollusks which have been used to equate geographically separated deposits (Horberg, 1956, p. 12–13; Leonard, 1950, 1951, p. 330–331).

SUMMARY

This study concerns the description and identification of a new species of conifer (larch) (?) from Yarmouth interglacial deposits in Indiana. The conifer *Larix* (?) *pleistocenicum* Beals, n. sp., is represented by the type specimen K-1 and the sections made from this specimen, located in the collection of Pleistocene wood, Department of Biological Sciences, Purdue University.

ACKNOWLEDGMENTS

The authors appreciate the helpful assistance and comments of E. S. Barghoorn, R. M. Kosanke, W. J. Wayne, H. Kohnke, A. T. Guard, and E. W. Stark during preparation of this manuscript.

REFERENCES

Bailey, I. W. & Faull, Anna, 1934, The cambium and its derivative tissues. IX. Structural variability in the redwood, *Sequoia sempervirens*, and its significance in the identification of fossil woods: Jour. of Arnold Arboretum, v. 15, p. 233–253.

Beals, H. O., 1957, A film impression method for the observation of minute features of wood anatomy: Am. Biol. Teacher, v. 19, p. 83–84.

——, 1958, New abrasive for sectioning water-soluble rocks: Jour. Sed. Petrology, v. 28, p. 233

—— & Guard, A. T., 1958, An abrasive paper technique for preparing sections of wood for microscopic study: Stain Tech., v. 33, p. 103–108.

Brown, H. P., Panshin, A. J. & Forsaith, C. C., 1949, Textbook of Wood Technology, v. 1. McGraw-Hill, New York, 652 p.

Coleman, A. P., 1901, Glacial and interglacial beds near Toronto: Jour. Geol., v. 9, p. 285–310.

Dawson, W. & Penhallow, D. P., 1889, On the Pleistocene flora of Canada: Geol. Soc. America, Bull., v. 1, p. 311–334.

Greguss, P., 1955, Identification of Living Gymnosperms. Akadeiai Kaido, Budapest, 263 p.

Horberg, Leland, 1956, Pleistocene deposits along the Mississippi Valley in central-western Illinois: Illinois Geol. Survey Rept. Inv. 192, 39 p.

Jane, F. W., 1956, The Structure of Wood. Macmillan Co., New York, 427 p.

Leonard, A. B., 1950, A Yarmouthian molluscan fauna in the midcontinent region of the United States: Kansas Univ. Paleont. Contrib., Mollusca, art. 3, 48 p.

——, 1951, Stratigraphic zonation of the Peoria loess in Kansas: Jour. Geol., v. 59, p. 323–332.

Wayne, W. J., 1955, *in* Indiana Geol. Survey Field Conf. Guidebook No. 8, p. 31–33.

Explanation of Plate 77

Fig. *1*—Transverse section of *L.* (?) *pleistocenicum* showing strand tracheid and several parenchyma cells. Note pitting in parenchyma. ×645.

2—Radial section of *L. laricina* K. Koch showing bordered pits and ray crossings. ×100.

3—Radial section of *L.* (?) *pleistocenicum* showing bordered pits and ray crossings. ×260.

4—Radial section of *L.* (?) *pleistocenicum* showing detail of bordered pits. ×645.

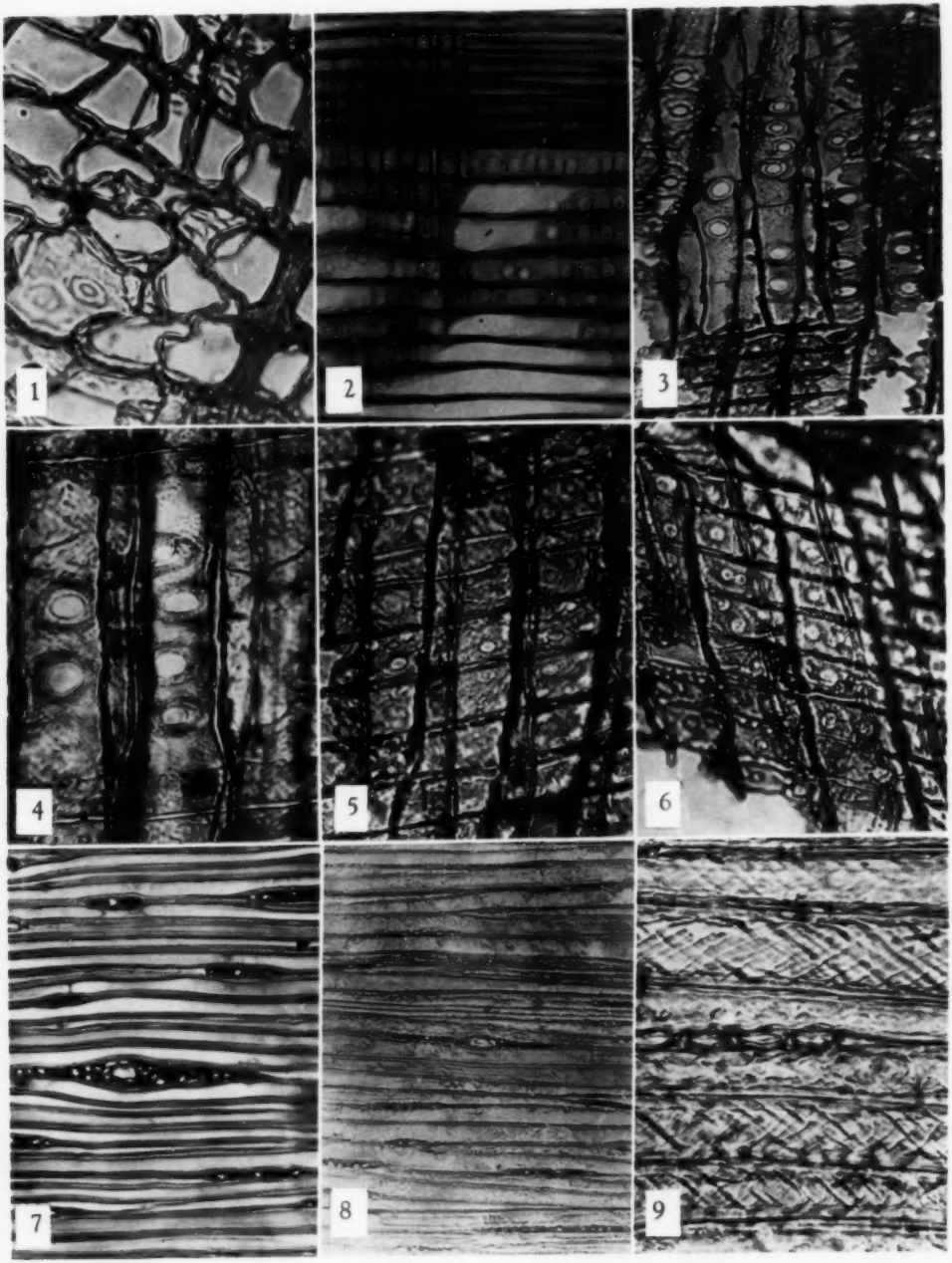
5—Radial section of *L.* (?) *pleistocenicum* showing detail of ray crossings (ray parenchyma). ×645.

6—Radial section of *L.* (?) *pleistocenicum* showing detail of ray crossings (ray tracheids). ×645.

7—Tangential section of *L. laricina* K. Koch showing fusiform ray with included resin canal. ×100.

8—Tangential section of *L.* (?) *pleistocenicum* showing fusiform ray with included resin canal. ×100.

9—Tangential section of *L.* (?) *pleistocenicum* showing spiral checking (?) in summerwood tracheids. ×645.


1
2
3
4
5
6
7
8
9

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

JOURNAL OF PALEONTOLOGY, V. 35, NO. 4, P. 673–736, PLS. 78–86, 17 TEXT-FIGS., JULY, 1961

THE PERMIAN AMMONOIDS OF AUSTRALIA

BRIAN F. GLENISTER AND W. M. FURNISH
State University of Iowa, Iowa City, Iowa

ABSTRACT—Nineteen species of Permian ammonoids are known from Australia. Two occur in the Sydney Basin of New South Wales and the remaining species come from the three major sedimentary basins of Western Australia. Practically the whole of the Permian Period is represented in Western Australia by marine or paralic sediments. The Australian ammonoid faunas are compared with those of the type-Lower Permian of the Ural Mountains and with the classic reference sections of the marine Lower and Upper Permian in other parts of the world. Subdivisions of the Permian System and correlations of the ammonoid-bearing strata are reviewed. It is concluded that in a world-wide sense the Permian System may be divided most usefully into the Asselian, Sakmarian, Artinskian, Guadalupian and Dzhulfian stages. The Artinskian is subdivided into the Aktastinian and Baigendzhinian substages, and the Guadalupian comprises the Wordian and Capitanian substages. A twofold series subdivision of the Permian System is utilized.

In Western Australia, *Thalassoceras wadei* Miller, *Juresanites campbelli* (Teichert & Glenister), *J. jacksoni* (Etheridge Jr.), *Metalegoceras clarkei* Miller, *M. striatum* Teichert, *M.* n. sp. (described herein), *Uraloceras irwinense* Teichert & Glenister, gen. indet. (described herein), and the new species *Propopanoceras ruzhencevi* are known from the Sakmarian; *Propinacoceras australe* Teichert, *P.* n. sp. (described herein), *Pseudoschistoceras simile* Teichert, *Paragastrioceras wandageense* Teichert, and *Neocrimites* sp. (described herein) occur in the Baigendzhinian Substage; and *Agathiceras applanatum* Teichert, *Pseudogastrioceras goochi* Teichert and *Popanoceras* sp. indet. (described herein) are known from the Wordian Substage. In the Sydney Basin of New South Wales, *Uraloceras pokolbinense* (Teichert) is known from beds which are assumed to be of Sakmarian age, and *Neocrimites meridionalis* Teichert & Fletcher occurs in strata referred to the Baigendzhinian Substage. *Pseudoschistoceras gigas* (Smith) from the Baigendzhinian Bitauni beds of Timor, is figured and compared with *P. simile* Teichert.

INTRODUCTION

AMMONOIDS are rare in the numerically large and varied Permian faunas of Australia. This rarity is in contrast to the situation in the type-Permian areas of the Soviet Union, where cephalopods constitute one of the dominant faunal elements and are commonly present in great profusion in sediments which yield few other fossils. In view of the chronologic sensitivity of the ammonoids and their ubiquitous occurrence in the Lower Permian of the Ural Mountains, it is not surprising that geologists have relied upon this nektonic group in the subdivision and correlation of the type-Permian. It follows that great chronologic significance for mondeal correlations should be attributed to the few ammonoid faunas known from Australia, and that evidence from this source should be weighted heavily

EXPLANATION OF PLATE 78

FIGS. *1–5*—*Thalassoceras wadei* Miller, from the Lower Permian Nura Nura Member of the Poole Sandstone, Fitzroy Basin, Western Australia. *1*, Bur. Min. Res. C.P.C. hypotype 1766, ×3; *2*, Uni. W. A. syntype 19988, ×4; *3*, Uni. W. A. hypotype 20143, ×2; *4,5*, Uni. W. A. syntype 19987, ×2.

6–13—*Propinacoceras australe* Teichert, from the Lower Permian strata in the Carnarvon Basin, Western Australia. *6,7*, Uni. W. A. figured specimen 20510, ×2, from the Wandagee Formation; *8,9*, Uni. W. A. holotype 20145, X1, from the lower Coolkilya Greywacke; *10*, Uni. W. A. figured specimen 20509, ×4, from the Wandagee Formation; *11–13*, Bur. Min. Res. C.P.C. hypotype 1764, ×1½, from the Bulgadoo Shale.

14,15—*Propinacoceras* n. sp., Bur. Min. Res. C.P.C. figured specimen 1765, ×2, from the Lower Permian Coyrie Formation, Carnarvon Basin, Western Australia.

against information derived from the associated benthonic groups.

All the known Permian ammonoids of Australia were examined during the preparation of the present work, with the exception that only selected specimens of *Juresanites jacksoni* have been studied. Nineteen species have been differentiated but only fourteen of them are named formally. Six of the named species and six of the unnamed forms are represented by only one or two specimens. Fairly large numbers of specimens of *Juresanites campbelli*, *Uraloceras irwinense* and *Propinacoceras australe* are available, but *Juresanites jacksoni*, which occurs by the hundreds, is the only ammonoid species in the Permian of Australia which is known from a large volume of well preserved material. Most of the Permian ammonoids from the Fitzroy Basin of Western Australia are limonitic, and are generally unsuitable for the detailed ontogenetic studies desirable in Paleozoic ammonoid taxonomy. Other Australian ammonoid species, with the exception of those from the Irwin River area of Western Australia, are so rare that specimens cannot generally be sacrificed for ontogenetic work. As a result, the present work makes few contributions to ammonoid taxonomy. However, it does add to our knowledge of the distribution of ammonoid taxa in both time and space, and yields information on the chronology of the Permian System in Australia.

The sutural formulae listed under generic headings, in the systematic part of the paper, utilize the symbols proposed by Ruzhencev (1949b). This procedure is being employed in most current Soviet ammonoid studies and has been published recently in English (Ruzhencev, 1960). In some cases, the nomenclature of our written descriptions of the suture differs slightly from the literal meanings for the symbols used.

Until recently, no uniform code governed the naming of stratigraphic units in Australia. Usage was inconsistent and varied with the geographic area and the workers concerned. An Australian Code of Stratigraphic Nomenclature was formulated recently (Raggatt, 1950). Minor additions, alterations and clarifications have been presented since the first appearance of the Code (Raggatt, 1953, 1956), but the new system has been accepted by practically all Australian stratigraphers. Stratigraphic nomenclature has been revised completely, in accordance with the Code, in several states, particularly Western Australia. The result is that stratigraphic information is now readily intelligible to the general reader. All the known Permian ammonoid occurrences are described herein with reference to the redefined stratigraphic units, and it is hoped that this will clarify the information available on the distribution of the group in question.

The present work does not attempt to evaluate and integrate the chronologic evidence yielded by the various Australian Permian faunal and floral elements, but merely to record the age assignments suggested by ammonoid studies. However, it is improbable that other faunal analyses will result in the establishment of age assignments which are substantially different from those presented herein. The reader is referred to recent publications (Thomas & Dickins, 1954; McWhae, Playford, Lindner, Glenister & Balme, 1958) for a general review of the correlation and age of the Permian formations of Western Australia.

EXPLANATION OF PLATE 79

FIGS. *1–3*—*Juresanites campbelli* (Teichert & Glenister). Uni. Melbourne holotype 1981, ×4, from the Lower Permian Holmwood Shale of the Perth Basin, Western Australia.

4–7—*Metalegoceras clarkei* Miller. Uni. W. A. hypotype 35776, ×2½, from the Lower Permian Nura Nura Member of the Poole Sandstone, Fitzroy Basin, Western Australia (see also pl. 80, figs. 1–5).

8–11—*Metalegoceras striatum* Teichert, from the Lower Permian Nura Nura Member of the Poole Sandstone, Fitzroy Basin, Western Australia. *8,9*, Bur. Min. Res. C.P.C. hypotype 1769, ×2½; *10,11*, Uni. W. A. holotype 20508, ×3.

1

2

3

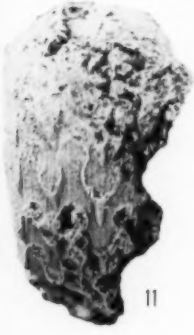
4

5

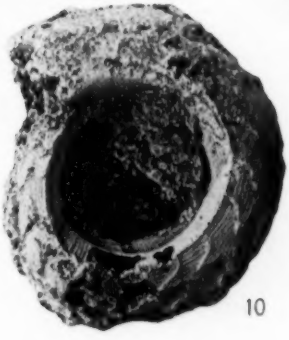
8

6

7



11



10

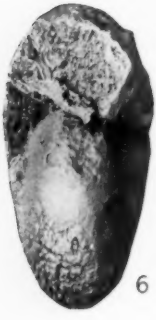
9

1

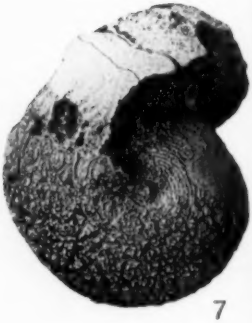
4

2

3



6



7

8

5

9

ACKNOWLEDGMENTS

We wish to thank the Director of the Commonwealth of Australia Bureau of Mineral Resources and the Chief Geologist, N. H. Fisher, for entrusting us with the description of their Paleozoic ammonoid collections and for the translations of several stratigraphic sections from the Soviet literature. Type species were generously lent by the University of Melbourne, the University of Sydney and the Australian Museum. Dorothy Hill, A. K. Denmead and F. S. Colliver kindly assembled the known late Paleozoic ammonoids of Queensland for study by the authors. M. F. Glaessner and R. O. Brunnschweiler provided comparative material from the Permian of Timor. Bureau of Mineral Resources paleontologists J. M. Dickins and G. A. Thomas read the manuscript and offered valuable suggestions; they also collected some of the specimens, and compiled much of the locality information. West Australian Petroleum Pty., Ltd., geologists R. M. L. Elliott, D. J. Guppy, A. W. Lindner, J. R. H. McWhae and P. E. Playford collected additional specimens and provided the authors with stratigraphic information. Curt Teichert read parts of the manuscript, and we have benefited greatly from his extensive knowledge of Australian biostratigraphy. B. E. Balme has been most helpful in discussions on the subdivision of the Permian and in making available the conclusions of his extensive microfloral studies. Anne Treloar Glenister was invaluable in translating parts of the Soviet literature and in preparing the final draft of some of the text-figures. Various phases of the report were made financially possible by Graduate Research Funds of the State University of Iowa and research grants from The University of Western Australia.

HISTORICAL REVIEW

The first published reference to an undoubted ammonoid from the Permian System of Australia was the description by Etheridge [1894, p. 36–37, pl. 7, figs. 9,12,14 (not 10,11,13)] of "*Goniatites* (*Prolecanites?*) *micromphalus*" Morris (1845) from the Branxton Subgroup of the "Upper Marine series" of New South Wales. Teichert & Fletcher (1943) described one of Etheridge's specimens as the holotype of a new species, *Adrianites* (*Neocrimites*) *meridionalis*. They demonstrated that this one specimen was the only undoubted ammonoid then known from the Permian of New South Wales, although gastropods and indeterminate fossils from this area had been referred to no less than eight genera, namely *Goniatites, Aganides, Sandbergeroceras, Prolecanites, Agathiceras, Gastrioceras, Pronorites*, and *Paralegoceras*.

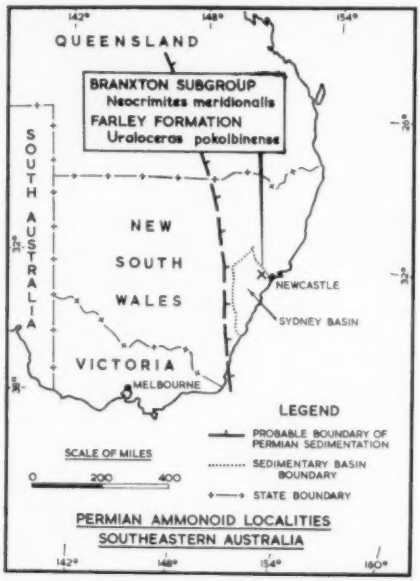
Two additional specimens were later recorded from the Farley Formation of New South Wales, and Teichert (1954) described them as a new species, *Pseudogastrioceras pokolbinense*. These three specimens remain the only undoubted Permian ammonoids known from the eastern two-thirds of the Australian continent. Both *Neocrimites meridionalis* and *Uraloceras pokolbinense* were considered to be most closely related to Artinskian species, and an Artinskian age was consequently ascribed to the upper beds of the Dalwood (Lower Marine) Group and the Branxton Subgroup of the Maitland (Upper Marine) Group.

EXPLANATION OF PLATE 80

FIGS. *1–5*—*Metalegoceras clarkei* Miller, from the Lower Permian Nura Nura Member of the Poole Sandstone, Fitzroy Basin, Western Australia. *1–3*, Uni. W. A. syntype 19985, ×2½; *4*, Bur. Min. Res. C.P.C. hypotype 1767, ×2; *5*, Bur. Min. Res. C.P.C. hypotype 1768, ×2½ (see also pl. 79, figs. 4–7).

6,7—*Agathiceras applanatum* Teichert. Uni. W. A. holotype 21451, ×2½, from the Upper Permian part of the Coolkilya Greywacke, Carnarvon Basin, Western Australia.

8,9—Gen. indet., Uni. W. A. figured specimen 35778, ×2½, from the Lower Permian Nura Nura Member of the Poole Sandstone, Fitzroy Basin, Western Australia.



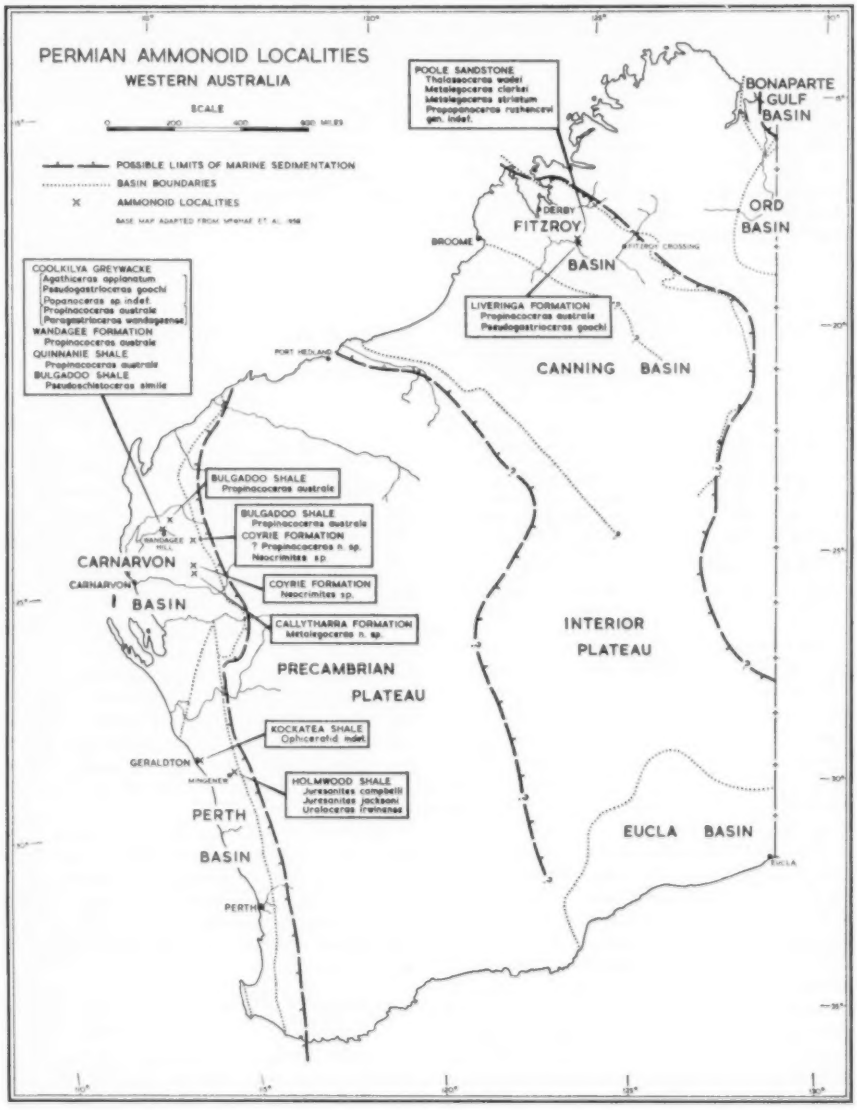
TEXT-FIG. 1

Jack & Etheridge (1892) described and figured a number of supposed goniatites from the "Permo-Carboniferous System" of Queensland. A study of their specimens by the present authors has revealed that the undoubted ammonoids in the collection are all of Carboniferous age. Some of the remaining specimens were derived from beds now known to belong in the Permian, but none of them is identifiable as an ammonoid. The Carboniferous ammonoids in Jack & Etheridge's work will be treated in a subsequent study of the Carboniferous ammonoids of Australia, and only the three Permian forms described by these authors as belonging in the Goniatitidae are considered below.

"*Goniatites micromphalus*" (Jack & Etheridge, 1892, p. 294) is not figured, but the description almost certainly refers to a Permian gastropod similar to *Warthia* Waagen (1880). "*Goniatites* sp. ind." (Jack & Etheridge, 1892, p. 295, pl. 15, fig. 5) is now numbered Queensland Geol. Surv. F1540. It was probably collected from Lower Permian strata in Rosella Creek near Gympie. Sutures are absent, and the specimen is referred to *Warthia* or a similar gastropod genus. The specimen figured by Jack & Etheridge (1892, pl. 14, fig. 7) as "*Goniatites* sp. ind." (Queensland Geol. Surv. F1539) does not seem to have been described in the text and no reference is made to it in any of the fossil lists. It was collected from beds of probable Lower Permian age in Kariboe Creek, near Kroombit in the Port Curtis area. No sutures are visible, and the specimen is probably a gastropod.

Whitehouse (1925) listed "*Girtyites* (?) sp." from the basal marine bed of the Permian "Middle Bowen Marine Series" of the Mt. Britton area of Queensland; *Girtyites* Wedekind is a junior synonym of *Paragastrioceras* Tchernow. Subsequent authors (see Teichert, 1942, p. 223) have referred to these strata as the "*Paragastrioceras* beds", but the Queensland specimen can not be identified with certainty as a cephalopod.

The first record of late Paleozoic ammonoids in Western Australia was the description by Etheridge (1907, p. 36–37, pl. 9, figs. 1–3) of a new species, "*Gastrioceras jacksoni*", from the "Carboniferous" sediments of the Irwin River district in the Perth Basin. This species is now referred to *Juresanites* and is known to be of Lower Permian age (Sakmarian Stage). Until the description of two Permian ammonoid species from the Fitzroy Basin (Miller, 1936), *Juresanites jacksoni* remained the only late Paleozoic ammonoid known from Western Australia. A history of the speculation on the affinities of the Irwin River species is of considerable interest, as this form played a singularly important part in the dating of the late Paleozoic strata from both eastern and western Australia. Haug (1911) briefly reviewed the late Paleozoic faunas of Australia and concluded that "*Gastrioceras jacksoni* . . . se rapprochant de diverses espèces du Carbonifère supérieur des États-Unis." A different view was taken by Haniel (1915, p. 63) in his consideration of the affinities of the Australian species. He referred *Gastrioceras jacksoni* to *Paralegoceras* but considered the preservation of illustrated specimens to be inadequate for close comparison with the Lower Permian *Paralegoceras sundaicum* from Timor. Dun & David (1923)


PERMIAN AMMONOID LOCALITIES
WESTERN AUSTRALIA
SCALE
0 200 400 600 MILES
POSSIBLE LIMITS OF MARINE SEDIMENTATION
BASIN BOUNDARIES
AMMONOID LOCALITIES
BASE MAP ADAPTED FROM SPRIGG ET AL. 1958
POOLE SANDSTONE
Thalassoceras waleri
Metalegoceras clarkei
Metalegoceras striatum
Propopanoceras rushencevi
gen. indet.
BONAPARTE GULF BASIN
ORD BASIN
DERBY
FITZROY BASIN
BROOME
FITZROY CROSSING
COOLKILYA GREYWACKE
Agathiceras applanatum
Pseudogastrioceras goochi
Popanoceras sp. indet.
Propinacoceras australe
Perrinoceras wandageense
WANDAGEE FORMATION
Propinacoceras australe
QUINNANIE SHALE
Propinacoceras australe
BULGADOO SHALE
Pseudoschistoceras simile
LIVERINGA FORMATION
Propinacoceras australe
Pseudogastrioceras goochi
PORT HEDLAND
CANNING BASIN
BULGADOO SHALE
Propinacoceras australe
BULGADOO SHALE
Propinacoceras australe
COYRIE FORMATION
? Propinacoceras n. sp.
Neocrimites sp.
WANDAGEE HILL
CARNARVON
CARNARVON BASIN
COYRIE FORMATION
Neocrimites sp.
CALLYTHARRA FORMATION
Metalegoceras n. sp.
INTERIOR PLATEAU
PRECAMBRIAN PLATEAU
KOCKATEA SHALE
Ophiceratid indet.
GERALDTON
MINGENEW
HOLMWOOD SHALE
Jurassinites campbelli
Jurassinites jacksoni
Uralocaras f'reinetes
PERTH BASIN
EUCLA BASIN
PERTH
EUCLA

TEXT-FIG. 2

later drew attention to "the great similarity, if not the absolute identity of *Gastrioceras Jacksoni*, Etheridge, from the Irwin River Coal-field, and *Paralegoceras sundaicum*, Haniel, from the Island of Letti." They were also aware of the Lower Permian age of the Timorian species. A large collection of well preserved ammonoid material was later submitted to H. Dighton Thomas, and he stated (1929) that the "affinities are with Upper Carboniferous forms, and as far as one may rely on this species it supports an Upper Carboniferous age for the bed which yields it in large numbers." David & Süssmilch (1931) apparently doubted the validity of chronologic conclusions reached earlier by Dun & David (1923) and accepted the unpublished "final conclusion" of Thomas, which they quoted as follows.

> "If all the characteristics be considered, *Paralegoceras jacksoni* finds a close analogue in the Pennsylvanian ammonoid *Gastrioceras excelsum* (Meek) from the middle coal-measures of Arkansas and east Kansas . . . *Paralegoceras jacksoni* has affinities then, not with Permian species, but with American Pennsylvanian species, as suggested by Haug, and would therefore indicate for the Irwin River goniatite bed an Upper Carboniferous (Upper Pennsylvanian) age."

As a consequence of this age assignment, all the major Paleozoic glacial horizons of Australia were referred to the Carboniferous, and this incorrect notion still persists in some recent foreign literature. Grabau (1931, p. 470), however, again drew attention to the close similarities between ammonoids from the Irwin River and those from the Lower Permian of Timor.

The first comprehensive account of the morphology and affinities of *Juresanites jacksoni* was given by Miller (1932). Until the appearance of his work the published information on the morphology of the species did not permit even generic assignment, as the internal suture had not been illustrated or described adequately. Miller showed that the similarities to Carboniferous forms were superficial and that the closest affinities were with the newly erected Lower Permian genus *Metalegoceras* Schindewolf. He suggested that the parent beds were probably of Artinskian age (Middle Permian of Miller, Lower Permian of recent Soviet papers and the present work). In a somewhat later paper Miller & Furnish (1940, p. 26) recognized the primitive form of the Irwin River species and consequently referred it to the Sakmarian Stage. Further support for a Sakmarian age was given in descriptive papers by Teichert (1942) and Teichert & Glenister (1952).

The first Permian ammonoids recognized from the Fitzroy Basin were described by Miller (1936) as the new species *Thalassoceras wadei* and *Metalegoceras clarkei*. Miller correlated the parent beds, now known as the Nura Nura Member of the Poole Sandstone, with the ammonoid beds of the Irwin River, and he considered them to be of Artinskian age. This Artinskian assignment was further endorsed by Miller & Furnish (1940, p. 27).

The main account of the Permian ammonoids of Western Australia was given by Teichert (1942). This author described the new forms *Propinacoceras australe*, *Paragastrioceras wandageense*, *Pseudogastrioceras goochi* and *Pseudogastrioceras* sp. from the Byro and Kennedy Groups in the Carnarvon Basin, and *Metalegoceras striatum* from the Nura Nura Member of the Poole Sandstone in the Fitzroy Basin. He referred the Poole Sandstone to the base of the Artinskian and the ammonoid beds of the Carnarvon Basin to a higher level in the same stage. Teichert (1944) subsequently described a new species, *Agathiceras applanatum*, from the Kennedy Group, and a new genus and species, *Pseudoschistoceras simile*, from the Byro Group of the Carnarvon Basin.

Teichert & Glenister (1952) added two new ammonoids, *Metalegoceras campbelli* and *Uraloceras irwinense*, to the species known from the Holmwood Shale of the Irwin River area. They ascribed a late Sakmarian age to the ammonoid beds of this locality.

REFERENCE ASSEMBLAGES FOR PERMIAN AMMONOIDS

Almost all geologists who are familiar with Permian faunas agree that ammonoids are a reliable group for intercontinental correlation of this system. It is fortunate that an abundance of well preserved ammonoids is present in some of the type-Permian areas and that these faunas have

TABLE 1—CORRELATION OF THE PERMIAN FORMATIONS OF WESTERN AUSTRALIA

Note: Single ammonoid specimens have been discovered in the Fossil Cliff Formation and the Mingenew Formation of the Perth Basin since submittal of this manuscript. Both specimens are considered in the addendum to the present study.

SERIES	STAGE / Substage	CANNING BASIN — FITZROY RIVER	CARNARVON BASIN — MINILYA RIVER	PERTH BASIN — GERALDTON / IRWIN RIVER
UPPER PERMIAN	DZHULFIAN	Blina Shale† (?)		Kockatea Sh.*† (?)
	Capitanian	Liveringa Formation		Indarra Beds
	GUADALUPIAN		Kennedy Group: Binthalya Sub Gp.	
	Wordian		Kennedy Group: Mungadan Ss.	
		Lightjack Mem.*	Kennedy Group: Coolkilya Gwke.*	
LOWER PERMIAN	ARTINSKIAN — Baigendzhinian	Noonkanbah Formation	Byro Group: Nalbia Gwke.	
			Byro Group: Wandagee Fm.*	
			Byro Group: Quinnanie Sh.*	
			Byro Group: Cundlego Fm.	Mingenew Fm.
			Byro Group: Bulgadoo Sh.*	Wagina Ss.
			Byro Group: Mallens Gwke.	Carynginia Fm.
			Byro Group: Coyrie Fm.*	Irwin River Coal Meas.
	Aktastinian	Poole Sandstone	Moogooloo Ss.	
			Gordalia Gwke.	High Cliff Ss.
	SAKMARIAN	Nura Nura Mem.*	Callytharra Fm.*	Fossil Cliff Fm.
		Grant Formation	Lyons Group	Holmwood Shale*
	ASSELIAN			Nangetty Fm.

* ammonoid bearing units
† may be Triassic

been described in a series of classic monographs.

Our detailed knowledge of the Lower Permian ammonoids of the Ural Mountains and adjacent areas permits direct comparison of geographically isolated faunas with those of the type areas. Furthermore, the stages and substages of the type-Lower Permian are adequately defined, although there is still no general agreement among Soviet paleontologists on the exact status of some of these subdivisions (Ruzhencev, 1956; Likharev *et al.*, 1958). The terms Asselian, Sakmarian and Artinskian are used in the current study to designate the stages of the Lower Permian.

Index cephalopods are virtually unknown from the type-Upper Permian of the Ural Mountains and adjacent areas. Consequently, the use of the standard Soviet stage nomenclature for this portion of the Permian is impracticable in ammonoid studies. However, a fairly complete understanding of ammonoid phylogeny enables us to construct a composite chronologic sequence of ammonoid-bearing Upper Permian strata.

We are adopting the well known sequence of West Texas-Coahuila as the main reference section for Upper Permian ammonoid studies. The stratigraphic nomenclature in this area is reasonably stable, and we there-

TABLE 2—CORRELATION OF SOME CLASSIC PERMIAN AMMONOID-BEARING STRATA

	STAGE	Substage	"Zone"	SICILY	URALS	CAUCASUS	SALT RANGE	TIMOR	WESTERN AUSTRALIA	TEXAS
UPPER PERMIAN	DZHULFIAN		Cyclolobus			Dzhulfa	Chideru		Kockatea	
	GUADALUPIAN	Capitanian	Timorites				Virgal	Amarassi	Liveringa	Capitan
		Wordian	Waagenoceras	Sosio				Basleo	Coolkilya	Word
LOWER PERMIAN	ARTINSKIAN	Baigendzhinian	Perrinites		Kungur			Tak Wai		San Andres
					Arti			Bitauni	Byro	Leonard
		Aktastinian								Clear Fork
	SAKMARIAN		Properrinites		Sterlitamak				Nura Nura	Upper Wichita
					Tastuba			Somahole	Holmwood	
	ASSELIAN				Kurmaya Uskalyk Syuren					Wolfcamp

fore propose to use the Guadalupian as the lower stage of the Upper Permian. A continuous sequence from the basal Guadalupian into the underlying Lower Permian strata is available in West Texas and Coahuila; ammonoids occur sporadically throughout the entire succession.

Phylogenetic studies indicate that a reference section for uppermost Permian must be selected elsewhere, as the Ochoan of West Texas lacks a normal marine fauna. The late Permian strata of the Dzhulfa area of Armenia, on the Soviet-Iranian border, are considered to be the best choice; the term Dzhulfian is used in the current study for the uppermost stage of the Permian. Dzhulfian biostratigraphy is well known through a series of classic works (Stoyanow, 1910), and it is believed that the sequence from the Upper Permian into the Triassic is complete in the Dzhulfa area.

It is most unlikely that the Guadalupian and Dzhulfian together cover the whole of Upper Permian time with neither overlap nor omission. However, phylogenetic studies on a wealth of ammonoids suggest that the two stages represent approximately the whole of this time interval.

The following summary of the geographic and chronologic distribution of some of the most significant Permian ammonoid assemblages is based mainly on published compilations by Miller & Furnish (1940) and Ruzhencev (1955, 1956). Subdivisions of the Permian System and correlations used in the present study are listed in Table 2.

ASSELIAN STAGE

The oldest strata known from the Permian of the Ural Mountains occur in the vicinity of the River Assel, Chkalov (Orenburg) region, where they overlie the sediments of the uppermost Carboniferous Orenburgian Stage. They were first described by Ruzhencev (1937) as the "Assel horizon." This same author later (1950a) elevated the rank of the unit to that of a substage of the Sakmarian Stage, and he subsequently defined it as the Asselian Stage (Ruzhencev, 1951, 1954). Most Soviet authors now accept the base of the Asselian as the lower limit of the Permian System, but there is still no general agreement as to the rank of the unit. Stratigraphers attending the Ural Conference, during February, 1956, were unwilling to credit the Asselian

with full stage standing, and resolved to use the division as the lower substage of the Sakmarian Stage. We are continuing to credit the Asselian with full stage status in order to avoid the inevitable confusion which would result from the use of "Sakmara" as a name for both a stage and a substage.

A few ammonoid genera persist from the Orenburgian into the Asselian, but the advent of the Permian is marked by the preponderence of new forms which give the Asselian assemblages a characteristic composition. Genera common to the Orenburgian and Asselian include *Neoaganides* Plummer & Scott, *Eothalassoceras* Miller & Furnish, and *Eoasianites* Ruzhencev. Four important families, the Perrinitidae, Metalegoceratidae, Popanoceratidae and the Paragastrioceratidae make their first appearance in the Asselian, where they are represented by the primitive genera *Properrinites* Elias, *Juresanites* Maximova, *Propopanoceras* Toumansky and *Paragastrioceras* Tchernow.

Asselian ammonoids are best known from the Southern Urals, but are also found in Texas (Wolfcamp Formation and lower part of the Hueco Limestone) and Timor (Somohole beds). *Properrinites* is considered as a zone fossil of the Asselian and Sakmarian Stages in North America and Timor, but is not known from the Urals. Asselian ammonoids have not been discovered in Australia, despite the fact that the late Sakmarian ammonoid fauna of the Nura Nura Member of the Poole Sandstone suggests that much of the Grant Formation, the Lyons Group and the Nangetty Formation of Western Australia may belong in this stage.

Sakmarian Stage

The ammonoids from the type area of the Sakmarian Stage, east of Chkalov, are known through the studies of Karpinsky (1874) and Ruzhencev (1950a); and faunas of comparable age are particularly well developed in the Aktyubinsk region of the Southern Urals (Ruzhencev, 1951, 1952). Many ammonoid genera are common to the Sakmarian and Asselian stages, although in numerous cases they are represented in the Sakmarian by species which show conspicuous advancement over those of the Asselian. Genera which make their first known appearance in the Sakmarian Stage include *Synuraloceras* Ruzhencev, *Metalegoceras* Schindewolf, *Uraloceras* Ruzhencev, *Medlicottia* Waagen, possibly *Thalassoceras* Gemmellaro, and *Crimites* Toumansky. All these genera belong in families which were present in the Asselian, but most are more highly evolved than their ancestors. Of particular significance are the genera which do not extend through into the Artinskian Stage. These include *Boesites* Miller & Furnish, *Prothalassoceras* Böse, *Juresanites* Maximova, *Synuraloceras* Ruzhencev and *Propopanoceras* Toumansky.

Ruzhencev (1955, 1956) restricted the definition of *Properrinites* Elias so as to confine this genus to the Asselian and Sakmarian stages. However, Miller & Furnish (1940, 1957b) do not recognize the validity of *Metaperrinites* Ruzhencev, a genus erected for advanced species which were previously included in *Properrinites*. The type of *Metaperrinites* is known from the upper Wichita Group of Northcentral Texas. This unit is included with reservation by Ruzhencev in the Aktastinian Substage of the Artinskian Stage.

Outside the Soviet Union, ammonoid facies of the Sakmarian Stage are known from Texas (Admiral Formation of the Wichita Group, and possibly the middle part of the Hueco Limestone in southern New Mexico), Western Australia (Nura Nura Member of the Poole Sandstone in the Fitzroy Basin, Callytharra Formation in the Carnarvon Basin, and Holmwood Shale in the Perth Basin) and possibly New South Wales (Farley Formation of the Dalwood Group).

Artinskian Stage

Ruzhencev (1956) gave a detailed account of attempts to define and subdivide the Artinskian Stage. He demonstrated that vertical variations in the cephalopod faunas provide the most reliable basis for subdivision of the unit. Although for historical reasons the Arti exposures must remain the type section of the Artinskian, the Aktast River in the Aktyubinsk area provides the best reference section. This results from the abundance of well preserved cephalopods in

both the Sakmarian and Artinskian of the Aktast River area, and from the clarity of the stratigraphic relationships. Ruzhencev (1956) proposed a subdivision of the Artinskian Stage into the lower Aktastinian Substage and the upper Baigendzhinian Substage.

Aktastinian Substage.—The ammonoid assemblage which characterizes the Aktastinian Substage has not been recognized positively outside the Southern Urals, but may be present in the upper Wichita Group of Texas (Miller & Furnish, 1940, p. 19).

Many genera extend into the Aktastinian from the underlying Sakmarian Stage. However, the base of the Artinskian in the Southern Urals is marked by the appearance of new genera and species and the spectacular numerical expansion of *Uraloceras* and *Paragastrioceras*. Ammonoid genera which make their first appearance include *Eothinites* Ruzhencev, *Neoshumardites* Ruzhencev, *Popanoceras* Hyatt, and *Propinacoceras* Gemmellaro.

Ruzhencev's tentative inclusion of the Clyde Formation (upper Wichita Group) of Texas within the Aktastinian Substage is based partly on the stratigraphic relationship of this formation to the overlying Clear Fork Group and partly on the ammonoid faunas. The Clear Fork Group is believed to be synchronous with the Leonard Formation of the Glass Mountain region and with the Baigendzhinian, so that the underlying Wichita Group is entirely older than the upper substage of the Artinskian. This correlation is confirmed by the relatively simple sutures of some of the ammonoids from the Clyde Formation.

Baigendzhinian Substage.—Ruzhencev (1956) has designated the Baigendzh area, on the boundary between the Aktyubinsk and Chkalov (Orenburg) districts of the Southern Urals, as the type of the Baigendzhinian Substage. Baigendzhinian ammonoids have long been known through the work of de Verneuil (1845) and Karpinsky (1889), and until recently almost all the numerous descriptions of Artinskian species have referred to forms from this substage.

The status of the Kungurian "Stage" and its relationship to the Baigendzhinian are still in doubt. The Kungurian sediments of the Urals were not deposited under normal marine conditions, and so they contain few ammonoids. Ruzhencev (1956) examined the available faunas and concluded that the ammonoids of the Kungurian are so similar to those of the Artinskian that the Kungurian should be considered as the upper part of the Baigendzhinian Substage. He suggested, on ammonoid evidence, that the Kungurian sediments of the Urals are the equivalent of the upper strata of the Bitauni beds of Timor and the Leonard Formation of Texas.

Ruzhencev (1956) noted that faunal differences between the Baigendzhinian of the Ural Mountains and the Leonard Formation of West Texas can be explained largely as a function of different geographic and ecologic provinces. However, the presence of advanced representatives of *Medlicottia* and *Stacheoceras*, and absence of *Metalegoceras*, in the upper Leonard Formation suggest that these strata are younger than the highest Baigendzhinian sediments of the Urals. Lack of detailed faunal information virtually excludes the use of the name "Kungurian" for such an interval.

Practically all of the ammonoid genera of the Aktastinian extend into the Baigendzhinian. However, new and more highly evolved species are commonly encountered in the higher substage. Genera which make their first appearance in the Baigendzhinian include *Pseudoschistoceras* Teichert, *Parapronorites* Gemmellaro, *Sicanites* Gemmellaro, *Atsabites* Haniel, *Paraceltites* Gemmellaro (the earliest representative of the Paraceltitidae), *Neocrimites* Ruzhencev, and "*Eumedlicottia*" Spath. Many of the genera and a few of the families known from the Baigendzhinian have not been recorded from the succeeding lower Guadalupian. These include the genera *Neopronorites* Ruzhencev, *Artinskia* Karpinsky, *Marathonites* Böse, *Paragastrioceras* Tchernow, *Metalegoceras* Schindewolf, *Uraloceras* Ruzhencev, *Eothinites* Ruzhencev, *Pseudoschistoceras* Teichert, and *Texoceras* Miller & Furnish. *Perrinites* Böse is uncommon in beds younger than the Leonard Formation but has been recorded (Miller & Furnish, 1957c) in the lowest limestone of the Word Formation.

The profound faunal changes in the ammonoids across the Baigendzhinian-

Guadalupian boundary are duplicated by many other fossil groups. As a result of these changes, practically all Soviet stratigraphers now accept the top of the Baigendzhinian (or "Kungurian") as the boundary between the Lower and Upper Permian.

Ammonoid facies of the Baigendzhinian Substage are more common than those of any other subdivision of the Permian. They are known from the Crimea (Kichik-Soraman, River Alma), Oman (limestones near Haushi), middle Asia (Bouz-téré beds of the Pamirs, Darwaz in Bukhara, and Sassyk-teke beds of the Zaalaisk Range), Japan (Maiya beds of the Kitakami Range in northeastern Honshu), Timor (Bitauni, Lidak and Taë Wei beds), Texas (Leonard, Bone Spring and Blaine-Dog Creek formations), New Mexico (San Andres Formation), Mexico (Las Delicias beds in Coahuila), Arizona (Colina and Naco limestones), Utah (Park City Formation), Idaho and Wyoming (Phosphoria Formation), Western Australia (Byro Group and lower part of the Coolkilya Greywacke in the Carnarvon Basin, and possibly the lower beds of the Lightjack Member of the Liveringa Formation in the Fitzroy Basin) and perhaps New South Wales (Branxton Subgroup of the Maitland Group in the Sydney Basin).

Guadalupian Stage

A survey of the literature indicates that very few ammonoids occur in the type-Upper Permian areas to the west of the Ural Mountains, and that reference sections for the Upper Permian must consequently be sought elsewhere. Many authors have adopted the profusely fossiliferous strata of West Texas for this purpose. These West Texas sections, particularly those of the Glass Mountains, contain a nearly complete series of ammonoid and fusuline faunas throughout the Lower Permian and part of the Upper Permian.

The term Guadalupian was proposed over fifty years ago by Girty, and this same author (1908) described some elements of the Guadalupian faunas. Detailed stratigraphic and faunal studies have subsequently established generalizations which apply to the overall West Texas area. For these reasons, we regard the Guadalupian as a stage representing the lower Upper Permian. It is convenient in faunal studies to subdivide this stage into substages based on the Word Formation and the Capitan Limestone (King, 1942).

Wordian Substage.—In the type area, the Word Formation consists of some 1200 feet of shales, sandstones, and thick fossiliferous limestones. There is no apparent time break between the Word Formation and the underlying Leonard Formation, which is predominantly a shale unit. Similarly, the Word Formation passes without apparent break into an overlying carbonate complex, representing the Capitanian. The Wordian Substage corresponds to the *Waagenoceras* Zone of earlier American literature and to the Sicilian "faunal assemblage" of Ruzhencev (1955) and others.

The Adrianitidae is one of the distinctive ammonoid groups of the Wordian Substage. This family is well represented earlier, but becomes more abundant and extremely diversified in the early Upper Permian. Another characteristic family, the Paragastrioceratidae, is common throughout the Permian, but changes almost completely in aspect at the boundary of these two Permian series. *Uraloceras* Ruzhencev and *Paragastrioceras* Tchernow occur abundantly in the Lower Permian of the Urals, but are relatively rare in other sections of comparable age. Neither genus has been recorded from Upper Permian strata. The oldest occurrence of *Pseudogastrioceras* is in beds of assumed late Artinskian age in North America; other known occurrences are of Upper Permian age, and the genus is characteristic of this series. Representatives of the Paraceltididae are rare and generalized in the late Lower Permian, but they expand in spectacular fashion in the Upper Permian. Members of the Cyclolobidae, which make their initial appearance in the Wordian, serve as the most reliable indices for the upper series.

The two most significant families for ammonoid correlation of the Lower Permian, the Metalegoceratidae and the Perrinitidae, become extinct for practical purposes at the Lower-Upper Permian boundary. *Metalegoceras* Schindewolf occurs in the Sakmarian and throughout the Artinskian of the Urals. The genus is also widespread in

other parts of the world, but is rare in the Leonard Formation and equivalent strata of West Texas. *Spirolegoceras* Miller, Furnish & Clark is assumed to be a close relative, but the exact affinities and age of the genus are still in doubt. *Perrinites* Böse characterizes the late Lower Permian of the American southwest and is known from Timor and middle Asia, but it has not been recorded from the type Artinskian. Additional representatives of this genus occur abundantly in the basal Word Formation and correlative strata in Northcentral Texas; the parent beds are not known to contain *Waagenoceras* Gemmellaro. There is, therefore, a slight discrepancy as far as stated ranges of these two zone fossils are concerned.

Capitanian Substage.—The name Capitan Limestone was first introduced in 1904 for the upper Guadalupian reef limestones of the Guadalupe Mountains. The formation has been redefined by various authors (*e.g.*, King, 1942), but the term Capitanian may be retained conveniently for Guadalupian strata which are younger than Wordian. The Capitan Limestone forms the top of the Permian sequence in the southern Guadalupe Mountains, but correlative strata in the Delaware Basin are overlain by the evaporites of the Ochoan. Bedded equivalents of the Capitan Limestone, in West Texas and Coahuila, contain abundant ammonoid faunas. The Capitanian Substage corresponds to the *Timorites* Zone of earlier American literature.

Most of the ammonoid genera from the Capitanian Substage are found also in the underlying Wordian Substage. New forms include *Kingoceras* Miller, *Xenodiscites* Miller & Furnish, *Timorites* Haniel, perhaps *Epadrianites* Schindewolf, and *Episageceras* Noetling.

Ammonoid beds of the Capitanian Substage occur in Texas, Mexico (upper Las Delicias beds), Timor (Amarassi beds), West Pakistan (Virgal Group of the Salt Range), and the Carnic Alps (Bellerophon Limestone).

Dzhulfian Stage

The uppermost Permian of the Russian Platform is represented largely by nonmarine sediments. Outside this province, several areas are known to develop ammonoid facies of uppermost Permian age. In general, the faunas of these strata are relatively undiversified, and the exact faunal and stratigraphic relationships with the Lower Triassic are uncertain. Various authors, including Stoyanow (1910), Spath (1934), and Ruzhencev (1955) have used the uppermost Permian beds of Dzhulfa, on the Armenian-Iranian border, as the main reference section for late Permian ammonoids. The lowermost Triassic (early Scythian) *Otoceras* Zone is present at Dzhulfa, and so the relationships between the Permian and Triassic systems can be observed in this area. The Dzhulfian is probably the approximate equivalent of the "*Cyclolobus* Zone" (*e.g.*, Miller & Furnish, 1940).

Cyclolobus seems to be the best index fossil of the Dzhulfian, but its usefulness is limited by its rarity. "*Eumedlicottia*" Spath, *Stacheoceras* Gemmellaro, *Episageceras* Noetling and *Pseudogastrioceras* Spath range into the Dzhulfian from the underlying Guadalupian. A variety of uppermost Permian representatives of the Otoceratacеae has been distinguished (Ruzhencev, 1959).

In addition to the type area, Dzhulfian ammonoid localities are known from the Punjab (Chideru beds of the Salt Range), the Himalayas (Chitichun and Kuling beds), China (Kheshan Series of Kwangsi), Madagascar (Ambilobé beds), eastern Greenland (Martinian beds), and possibly Western Australia (Kockatea Shale of the Perth Basin) and New Caledonia.

AGE OF THE AMMONOID-BEARING PERMIAN FORMATIONS OF AUSTRALIA

Various authoritative statements on the stratigraphy of the Australian formations which have yielded Permian ammonoids are readily available. The reader is referred to the work of McWhae, *et al.* (1958) for a comprehensive review of the stratigraphy of Western Australia, to Condon (1954) and Teichert (1952, 1957) for information on the Carnarvon Basin, and to Guppy, Lindner, Rattigan & Casey (1958) for an account of the stratigraphy of the Fitzroy Basin. It should be noted that the manuscript of McWhae *et al.* was completed when the present study was in its preliminary stages, and that the writers do not subscribe to all

the Permian correlations suggested in the earlier work. The latest comprehensive account of the late Paleozoic of eastern Australia is that of David (1950). In addition, Hill (1952) has given a survey of the Gondwana stratigraphy of Queensland; and an authoritative account of Queensland geology is now available in Hill, Denmead *et al.* (1960). Stratigraphic nomenclature for New South Wales was reviewed by Vallance (1959).

Holmwood Shale.—This formation crops out in the northern part of the Perth Basin of Western Australia. It has yielded the ammonoids *Juresanites jacksoni* (Etheridge), *J. campbelli* (Teichert & Glenister), and *Uraloceras irwinense* Teichert & Glenister; together with a fauna of conulariids, serpulids, bryozoans, brachiopods, pelecypods, gastropods and nautiloids (Teichert & Glenister, 1952). All the faunal elements occur in thin beds, each of which is separated from adjacent fossiliferous horizons by considerable thicknesses of apparently barren strata. Miller & Furnish (1940, p. 26) were the first authors to suggest a Sakmarian age for the Holmwood Shale. Subsequent workers (Teichert, 1942; Teichert & Glenister, 1952) endorsed this age assignment.

The association of *Juresanites* and *Uraloceras* in the Holmwood Shale leaves little doubt that this formation should be referred to the Sakmarian Stage, as *Juresanites* is unknown above the Sakmarian and *Uraloceras* has not been found beneath it. It is demonstrated in the systematic part of the present work that *Juresanites jacksoni* is closely similar in sutural development to *J. kazakhorum* Ruzhencev, which is found in faunal assemblage 4 of the early Tastubian Karamurun series in the Southern Urals

TABLE 3—STRATIGRAPHIC DISTRIBUTION OF AMMONOID GENERA KNOWN FROM THE PERMIAN OF AUSTRALIA

SERIES / STAGE / Substage	CARB.	L. PERMIAN				U. PERMIAN		
				ARTINSKIAN		GUADALUPIAN		
	ORENBURGIAN	ASSELIAN	SAKMARIAN	Aktastinian	Baigendzhinian	Wordian	Capitanian	DZHULFIAN
AGATHICERAS Gemmellaro	•	•	•	•	•	•		
JURESANITES Maximova		•	•					
PARAGASTRIOCERAS Tchernow		•	•	•	•			
PROPOPANOCERAS Toumansky		•	•					
METALEGOCERAS Schindewolf			•	•	•			
URALOCERAS Ruzhencev			•	•	•			
THALASSOCERAS Gemmellaro			•	•	•	•		
POPANOCERAS Hyatt				•	•	•		
PROPINACOCERAS Gemmellaro				•	•	•	•	
PSEUDOSCHISTOCERAS Teichert					•			
NEOCRIMITES Ruzhencev					•	•	•	
PSEUDOGASTRIOCERAS Spath					•	•	•	•

(Ruzhencev, 1952, p. 39). The close affinities of these two species suggest that the ammonoid-bearing Beckett Member of the Holmwood Shale is of comparable age to the Tastubian (lower) part of the Sakmarian Stage. It follows that on the basis of stratigraphic position the underlying sparsely fossiliferous Nangetty Formation may be referable to the Asselian Stage.

Juresanites campbelli and *Uraloceras irwinense* are found together in beds 150 feet stratigraphically above the horizon of *J. jacksoni*. The unusually small size of *J. campbelli* makes detailed comparisons difficult, and so reduces the chronologic value of the species. *Uraloceras* makes its first appearance in faunal assemblage 5 of the late Tastubian (middle Sakmarian Stage) of the Southern Urals (Ruzhencev, 1952, p. 40). The specimens from the Irwin River are atypically small, but their stratigraphic distribution is compatible with the permissible range in age of beds between the Beckett Member and the Fossil Cliff Formation. It is suggested that the Fossil Cliff Formation is equivalent to the Sterlitamakian (faunal assemblage 6, or uppermost Sakmarian Stage; Ruzhencev, 1952, p. 40). Consequently, it seems probable that the *Uraloceras* beds are of middle Sakmarian age.

Nura Nura Member of the Poole Sandstone.—The Nura Nura Member is a thin but richly fossiliferous marine unit which is exposed sporadically in the Fitzroy Basin of Western Australia, at the base of the Poole Sandstone. The ammonoids *Thalassoceras wadei* Miller, *Metalegoceras clarkei* Miller, *M. striatum* Teichert, *Propopanoceras ruzhencevi*, n. sp., and gen. indet. (described herein) occur near the top of the member, together with a fauna consisting largely of bryozoans, brachiopods, gastropods and pelecypods. Miller (1936, p. 685) ascribed an Artinskian age to the Nura Nura Member, and Teichert (1942, p. 222) referred it to the base of the Artinskian. Subsequent workers (Thomas & Dickins, 1954, p. 221) have supported Teichert's age designation. The subsequent discovery of an advanced species of *Propopanoceras* now necessitates a slight revision of this assignment.

The Nura Nura Member can not be considered older than the Sakmarian Stage, as *Metalegoceras* makes its first known appearance in the middle Sakmarian. The Fitzroy Basin species of *Metalegoceras* are obviously more advanced than the Tastubian metalegoceratids from the Perth Basin, but the development of their sutures is compatible with either a late Sakmarian or Artinskian age. *Metalegoceras* is known to extend into the Baigendzhinian Substage. *Thalassoceras* ranges from the Sakmarian Stage into the lower Guadalupian, but the Australian species does not permit a confident age assignment within this possible range. *Propopanoceras* makes its first known appearance in the late Asselian of the Urals and extends upward through the overlying Sterlitamakian late Sakmarian Stage. It is replaced at the Sakmarian-Artinskian boundary by its undoubted descendant, *Popanoceras*. *Propanoceras ruzhencevi* is an advanced representative of the genus, and the most closely related form is *P.* n. sp. (Ruzhencev, 1951, p. 173–174) from the Sterlitamakian of the Urals. These facts suggest that the Nura Nura Member is the equivalent of the uppermost Sakmarian Stage of the Urals section (Ruzhencev, 1952, p. 40–41).

Callytharra Formation.—This thick marine unit is widely exposed in the Carnarvon Basin of Western Australia. Only one specimen of an ammonoid, described herein as *Metalegoceras* n. sp., is known from the formation, but the associated fauna (Teichert, 1952, p. 122) is one of the richest in the Permian formations of the Carnarvon Basin. Over 100 species have been differentiated, and the foraminifers, corals, bryozoans, echinoderms and brachiopods are particularly abundant.

Hosking (1931, p. 9) was the first to suggest a correlation between the Callytharra Formation in the Carnarvon Basin and the Fossil Cliff Formation in the Perth Basin. Teichert's extensive biostratigraphic studies supported this correlation and extended it to include the Nura Nura Member in the Fitzroy Basin (1941, p. 393). Subsequent work has confirmed these correlations (Thomas & Dickins, 1954, p. 219).

The sutural development of *Metalegoceras* n. sp., is compatible with either a late Sakmarian or an Artinskian age for the Callytharra Formation. However, in view of the correlation of this formation with the Nura Nura Member of the Poole Sandstone

and the Fossil Cliff Formation, it is believed to be of late Sakmarian age.

Coyrie Formation.—This formation is exposed over extensive areas of the Carnarvon Basin of Western Australia. It has yielded the ammonoids described herein as *Neocrimites* sp. and *Propinacoceras* n. sp., together with an extensive fauna of foraminifers, bryozoans, crinoids, brachiopods, pelecypods and gastropods. Both *Neocrimites* and *Propinacoceras* make their first known appearance in the Artinskian Stage and their ranges extend into the late Guadalupian. The Western Australian species of *Neocrimites* is strikingly similar to *N. fredericksi* from the Baigendzhinian Substage of the Urals. Ammonoid occurrences through a considerable thickness of section, as high as the lower part of the Coolkilya Greywacke, can be demonstrated to belong in the Baigendzhinian. It therefore appears that the Coyrie Formation should be correlated with the lower part of this substage.

Bulgadoo Shale.—This marine formation occurs in the Carnarvon Basin of Western Australia. It has yielded a small but significant fauna which includes the shark *Helicoprion davisii* (Woodward), and the ammonoids *Propinacoceras australe* Teichert and *Pseudoschistoceras simile* Teichert. Details of the suture in *P. australe* indicate that this taxon should be included in the group of species typified by *P. knighti* Miller & Furnish. Other representatives of this group of species are known from North America, middle Asia and Timor; and all documented occurrences are restricted to the Baigendzhinian Substage. The only species of *Pseudoschistoceras* known from outside of Australia is *P. gigas* (Smith), which occurs in the Baigendzhinian Bitauni beds of Timor. It is thus evident that the ammonoid fauna of the Bulgadoo Shale, and its stratigraphic position relative to other dated formations, indicate a Baigendzhinian age for the unit.

Quinnanie Shale.—This unit is exposed in the Carnarvon Basin of Western Australia. It is relatively unfossiliferous but has yielded the ammonoid *Propinacoceras australe* Teichert. The formation is believed to be of Baigendzhinian age, in view of the affinities of *P. australe* discussed above, and because of the stratigraphic position of the unit with respect to adjacent dated beds.

Wandagee Formation.—This formation is one of the most richly fossiliferous units exposed in the Carnarvon Basin of Western Australia; Teichert (1952, p. 128) estimated that approximately 150 fossil species are present. The profusion of the crinoid *Calceolisponqia* is a noteworthy feature of the fauna; other significant elements include the corals, brachiopods and the ammonoid species *Propinacoceras australe* Teichert. The Baigendzhinian affinities of this ammonoid have been established, and the age is confirmed by the position relative to dated beds above and below.

Coolkilya Greywacke.—Considerable uncertainty surrounds the definition of the Coolkilya Greywacke (Condon, 1954, p. 85–96; Teichert, 1957, p. 67), a formation exposed in the Carnarvon Basin of Western Australia. Practically all the ammonoids available from this formation were collected by Teichert, and it is difficult to place them in Condon's measured sections. Consequently, the Coolkilya Greywacke is used in the sense of Teichert (1952) throughout the present work, unless a statement appears to the contrary; and ammonoid occurrences are referred to Teichert's stratigraphic section (1952, p. 117). Several richly fossiliferous horizons are known. The ammonoids *Paragastrioceras wandageense* Teichert and *Propinacoceras australe* Teichert are found in association with *Helicoprion davisii* (Woodward) in the lower 100 feet of the formation. *Pseudogastrioceras goochi* Teichert makes its first known appearance approximately 350 feet above the base of the Coolkilya Greywacke; its known range extends to within 90 feet of the top of the formation, and if is found in association with *Agathiceras applanatum* Teichert and *Popanoceras* sp. indet. in these upper beds. The reputed presence of *Propinacoceras australe* in the upper beds of the Coolkilya Greywacke (Teichert, 1952, text-fig. 2) is yet to be confirmed; as no reference to this occurrence appears in the text of any of Teichert's papers, and the fossil to which his identification refers has not been located in the available collections. However, it is possible that the species in question, or a related form, has been observed in the upper part of the Coolkilya Greywacke, for *Pro-*

pinacoceras is known from beds as young as the late Guadalupian.

Paragastrioceras is exceedingly common in the Lower Permian of the Urals, but the genus is unknown in beds younger than the Baigendzhinian Substage. This, together with the Baigendzhinian affinites of *Propinacoceras australe*, suggests that at least the lower 100 feet of the Coolkilya Greywacke should be referred to the Baigendzhinian.

Agathiceras is an unusually stable genus which ranges from the Carboniferous into the lower Guadalupian. The Western Australian species does not permit a confident age assignment within these limits. *Pseudogastrioceras* is common in the Guadalupian of Texas and Coahuila, and in the Sosio Limestone of Sicily. It is characteristic of the Guadalupian, but is also found in Dzhulfian strata. Additional occurrences have been documented in strata of assumed Artinskian age (Miller, Furnish & Clark, 1957). The presence of *Pseudogastrioceras goochi* in the upper part of the Coolkilya Greywacke thus suggests a Guadalupian age for this part of the formation, and the stratigraphic position with respect to the underlying Baigendzhinian beds, together with the occurrence of *Agathiceras*, indicates a correlation with the Wordian Substage. The Baigendzhinian-Wordian boundary probably lies somewhere between 100 feet and 350 feet above the base of the Coolkilya Greywacke; that is, between the uppermost beds known to contain *Paragastrioceras* and the lowest known occurrence of *Pseudogastrioceras*. However, the possibility of a Lower Permian age for the entire Coolkilya Greywacke can not be eliminated completely.

Thomas & Dickins (1954) presented conclusions on the correlation of the marine Permian formations of Western Australia which were reached largely from their own studies of brachiopods, gastropods and pelecypods, together with the earlier biostratigraphic work of Teichert. They suggest close affinities between the pelecypods of the Guadalupian Basleo and Amarassi beds of Timor and those from the Coolkilya Greywacke and the lower Liveringa Formation of Western Australia (1954, p. 222). However Dickins (written communication, December 5, 1958) no longer subscribes to these implied correlations.

Liveringa Formation.—The Liveringa Formation is a thick paralic unit which is exposed widely in the Fitzroy Basin of Western Australia. Two of its components members are known to contain rich marine faunas, and the intermediate beds have yielded abundant plant remains of the *Glossopteris* flora. The lowest beds of the formation are referred to the Lightjack Member; they contain the ammonoid *Pseudogastrioceras goochi* Teichert and probably also *Propinacoceras australe* Teichert. These two species are also known from the Coolkilya Greywacke of the Carnarvon Basin and suggest a correlation with that formation.

Propinacoceras australe makes its first known appearance in the Bulgadoo Shale of the Carnarvon Basin, and the highest authenticated occurrence in that area is in the bottom 100 feet of the Coolkilya Greywacke. All occurrences in the Carnarvon Basin are referred to the Baigendzhinian Substage, for reasons discussed under the Coolkilya Greywacke heading. J. M. Dickins has suggested to the authors that the single specimen of *P. australe* known from the Fitzroy Basin may have come from the top of the Noonkanbah Formation, although its derivation from the overlying basal beds of the Liveringa Formation seems more probable.

Pseudogastrioceras goochi Teichert is known from the middle and upper beds of the Coolkilya Greywacke in the Carnarvon Basin. Evidence already presented indicates that all the known occurrences of the species in that area are of probable lower Guadalupian age. The two representatives from the Fitzroy Basin were collected in the Lightjack Member from approximately 55 feet above the base of the Liveringa Formation; the Lightjack attains a thickness of 65 feet in the type section.

From this information, it appears that the upper beds of the Lightjack Member are of early Upper Permian age. The presence of *Propinacoceras australe* in either the lower part of the Liveringa Formation or the upper beds of the Noonkanbah Formation may suggest that the Baigendzhinian-Wordian boundary lies in the lower beds of the Lightjack Member.

Thomas & Dickins (1954) concluded that the fauna of the upper Liveringa Formation has strong affinities with those of the Middle and Upper *Productus* Limestones of the Salt Range. They ascribed a Tatarian age to the fauna, but only the Upper *Productus* Limestone is considered as Tatarian (Dzhulfian) in the present work, and the Middle *Productus* Limestone is correlated with the Capitanian Substage.

Kockatea Shale.—This unit is a sparsely fossiliferous marine formation, known mainly from the Geraldton-Mullewa and Beagle Ridge districts of the Perth Basin of Western Australia, but also recognized in thin exposures of the same general area. A single ammonoid from this formation (Uni. W.A. 37086) is available to us for study, but numerous comparable forms have been secured recently from the Beagle Ridge Bore by the Bureau of Mineral Resources (J. M. Dickins, written communication, 1959). Our specimen came from a depth of 1470 feet in the Geraldton Racecourse Bore, where it was associated with a small conodont fauna, numerous hystrichosphaerids and plant microfossils. B. E. Balme (personal communication) believes that the microflora and hystrichosphaerids are practically identical with those recovered from the Blina Shale of the Fitzroy Basin, and he correlates these two units.

We have assembled extensive collections of Upper Permian and Lower Triassic ammonoids, for comparative purposes, in an attempt to designate a precise age for the Kockatea Shale. The Geraldton specimen is referable to the Ophiceratidae, but information on the systematics and chronologic distribution of this and related Permian groups is somewhat disorganized, so that generic and age assignments cannot be given with any degree of confidence. Nevertheless, the species should probably be regarded as Dzhulfian or early Scythian in age.

Farley Formation.—The Farley Formation is the richly fossiliferous uppermost unit of the Dalwood (Lower Marine) Group in the Sydney Basin of New South Wales. It has yielded the ammonoid *Uraloceras pokolbinense* (Teichert) and a large assemblage of brachiopods, pelecypods and gastropods. The unusual form of the suture in *U. pokolbinense* and the uncertainty of its generic affinities permit only limited chronologic significance to be attributed to the species. However, the general faunal affinities of the Farley Formation appear to be with the Fossil Cliff Formation in the Perth Basin of Western Australia (Teichert, 1941), and the age of the formation is, therefore, probably late Sakmarian.

Branxton Subgroup.—The Branxton Subgroup includes the lower part of the Maitland (Upper Marine) Group in the Sydney Basin of New South Wales. It has yielded the ammonoid *Neocrimites meridionalis* Teichert & Fletcher and, in some horizons, a notable profusion of bryozoans and corals. *Neocrimites* is known to range through beds of Baigendzhinian and Guadalupian age. A restricted range within the generic limits can not be designated with confidence. However, general faunal comparisons suggest a Baigendzhinian age for the Branxton Subgroup (Teichert, 1941).

SYSTEMATIC PALEONTOLOGY

Family MEDLICOTTIIDAE Karpinsky, 1889

Ruzhencev (1949a, p. 93–162) treated the medlicottiids in great detail. He included the following genera in the family Medlicottiidae: *Prouddenites* Miller (1930), *Daixites* Ruzhencev (1941), *Uddenites* Böse (1919), *Propinacoceras* Gemmellaro (1887), *Artioceras* Ruzhencev (1947), *Synartinskia* Ruzhencev (1939), *Sicanites* Gemmellaro (1887) *Akmilleria* Ruzhencev (1940), *Artinskia* Karpinsky (1926), *Aktubinskia* Ruzhencev (1947), *Medlicottia* Waagen (1880), *Neogeoceras* Ruzhencev (1947), and *Eumedlicottia* Spath (1934). Miller & Furnish (1957b, p. 72–74) reviewed the family and placed some of these generic names in synonymy. However, they retained the subfamily Uddenitinae Miller & Furnish, 1940, and recognized that the genus *Uddenoceras* Miller & Furnish, 1954, belongs here. In a more recent tabulation, Ruzhencev (1957, p. 56) employs three additional familial names based on relatively obscure medlicottiids: (1) Episageceratidae Ruzhencev, 1956, for *Episageceras* Noetling, 1904 (type: *Sageceras* (*Medlicottia*) *wynnei* Waagen, 1880, OD) and two related genera known to occur rarely in Upper Permian and Lower Triassic strata; (2) Shikhanitidae Ru-

zhencev, 1951, for a single species and genus, *Shikhanites* Ruzhencev, 1938 (type: *S. singularis* Ruzhencev, 1938, OD), based on a unique Lower Permian specimen from Tra Tau shikhan in the Sterlitamak region to the west of the Ural Mountains; and (3) Sundaitidae Ruzhencev, 1957, for the peculiar genus *Sundaites* Haniel, 1915 (type: *S. levis* Haniel, 1915, OD), based on six specimens from the Amarassi beds of Timor.

Studies of materials now available to us suggest that several of these taxa are not based on reliable characters. For example, the septal flexures show more instability than indicated by Ruzhencev's diagrams and descriptions (*e.g.*, 1949a, p. 94). Only the few problems of medlicottiid nomenclature which involve the Australian species will be considered further in the current study.

Genus PROPINACOCERAS Gemmellaro, 1887

Type species.—*Propinacoceras Beyrichi* Gemmellaro, 1887, pl. 5, figs. 12–15.

Diagnosis.—Shell discoidal; venter flattened, with median groove flanked by two rows of conspicuous transversely elongate nodes. Suture consists of a narrowly trifid ventral lobe, some ten pairs of external lateral and auxiliary lobes, a series of dorsolateral lobes, numbering three or four less than the external laterals, and a bifid dorsal lobe. External lobes on ventral part of flanks strongly bifid; lobes on dorsal part of flanks bifid or entire; dorsolateral lobes entire. Fourth or fifth external lateral lobe joined by septal crenulation to first internal lateral lobe in moderate sized specimens; larger individuals probably join this internal element with the sixth external. First lateral lobe either shallower or deeper than corresponding second lateral. First lateral saddle wide, undivided on ventral flanks, divided by two to four adventitious subdivisions adorally, simple or divided by one entire or bifid adventitious lobe on dorsal flanks. Remaining saddles undivided. The most common sutural type is represented by the following formula:

$$(V_2V_1V_2)a_{1\text{-}1}a_{1\text{-}1}a_1U_1U^1U^2U^3\ldots$$

A total of over twenty U^n lobes may be present in the external and internal suture. The degree of subdivision of the first lateral saddle is somewhat variable, and the type species has the following formula:

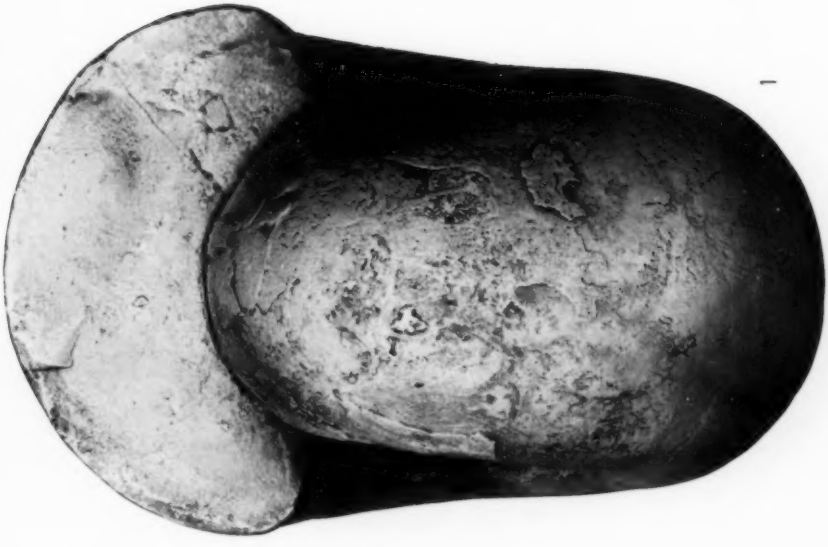
$$(V_2V_1V_2)a_1a_1U_1U^1U^2U^3\ldots$$

Discussion.—*Propinacoceras* may be differentiated from other Permian medlicottiids by its undivided ventral flank of the first lateral saddle. The genus *Artioceras* Ruzhencev, 1947 (type: *Propinacoceras rhipaeum* Ruzhencev, 1939, OD) was proposed for related forms that differ only slightly from typical *Propinacoceras*. *A. rhipaeum* possesses a first lateral lobe which is significantly deeper than the corresponding second lateral, and these two elements are subequal in size. Also, at maturity, this species has the first dorsolateral lobe joined by a septal flexure to the fifth external lateral lobe. It is believed that the relative depth of the first and second lateral lobes is of limited significance in medlicottiid taxonomy; the first lateral lobe was the deepest and most prominent sutural element during early ontogenetic stages in all medlicottiids, but changed rapidly in most forms to a subsidiary status. Some genera, such as *Artinskia* and *Medlicottia*, as now defined (Ruzhencev, 1949a, p. 131–140, 145–154), include both types of development. The exact contours of the septum are not known in most medlicottiids. However, in our experience, the relationship of external to internal septal crenulations is largely a function of conch form; it may change radically during ontogenetic development, or differ markedly in otherwise closely related forms.

EXPLANATION OF PLATE 81

FIGS. *1,2*—*Juresanites jacksoni* (Etheridge). Uni. W. A. hypotype 35779, ×1, from the Lower Permian Holmwood Shale, Perth Basin, Western Australia.

2



1

2

1

For example, the specimens of *Propinacoceras galilaei* Gemmellaro available to us have the fifth external paired with the first dorsolateral lobe, and yet have a relatively small first lateral lobe as well as other characteristics of type *Propinacoceras*. This Sicilian species also resembles *P. rhipaeum* in that the sixth external joins the second and third dorsolateral lobes. In view of all these considerations, we are unable to retain *Artioceras* as a separate genus.

The known species of *Propinacoceras* have been grouped into three morphological divisions (Ruzhencev, 1956, p. 97), based on the outline and degree of subdivision of the first external saddle and the first lateral lobe.

Distribution.—*Propinacoceras* is known from the Aktastinian Substage to the early Guadalupian Stage of the Soviet Union, but ranges elsewhere into the late Guadalupian. The genus is represented by the following species: *P. rhipaeum* Ruzhencev, *P. aktubense* Ruzhencev and *P. ajense* Maximova from the Artinskian of the Southern Urals, *P. galilaei* Gemmellaro and *P. affine* Gemmellaro from the Permian of Sicily and the Crimea, *P. beyrichi* Gemmellaro from the Permian of Sicily, *P. knighti* Miller & Furnish from the Leonard and Bone Spring formations and the San Andres Group of Texas, *P. americanum* Miller & Warren from the Cache Creek Group of British Columbia, *P. simile* Haniel from the Bitauni beds of Timor, *P. australe* Teichert from the Permian of Western Australia, and possibly *P.* n. sp. (described herein) from the Coyrie Formation of Western Australia. An unnamed species of *Propinacoceras* has been described (Miller, 1944) from the late Guadalupian of Coahuila. Several imperfectly known additional species have been recorded from the Permian of middle Asia (Toumansky, 1949.

PROPINACOCERAS AUSTRALE Teichert, 1942
Pl. 78, figs. 6-13; text-fig. 3A

Propinacoceras australe TEICHERT, 1942, Jour. Paleontology, v. 16, p. 224–226, pl. 35, figs. 2–7, text-fig. 3C.

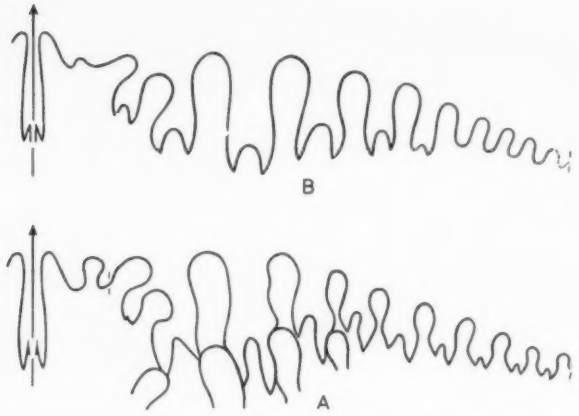
Description.—The holotype and fifteen additional specimens of this species are known to the authors. Most of the specimens are either fragmentary or immature, and only two well preserved large specimens (Uni. W. A. holotype 20145 and Bur. Min. Res. C.P.C. hypotype 1763) are available. Shell measurements and proportions are given in Table 4.

A notable feature of the shell proportions is the rapid decrease in the size of the umbilicus which begins at a conch diameter of approximately 5 mm. The flanks of mature whorls are almost flat and parallel to each other. A shallow longitudinal groove along the flattened venter separates two rows of transversely elongate nodes across the narrowly rounded ventrolateral shoulders. These ventrolateral nodes continue faintly across the flanks of immature specimens, where they form a high lateral salient, but they do not persist across the flanks of large specimens. Delicate ribs appear on the ventrolateral flanks close to the ventrolateral shoulder; they are not directly related to the nodes and are slightly more numerous. These ribs are known to form a prominent sinus across the ventrolateral flanks, but they are not preserved across the remainder of the flanks in any specimen in the authors' collections.

The mature suture consists of a deep narrow trifid ventral lobe, ten pairs of bifid lateral lobes, seven pairs of dorsolateral lobes, and a deep narrow dorsal lobe. The first dorsolateral lobe is joined by a septal crenulation to the fourth lateral lobe, and all succeeding internal and external lateral lobes are similarly connected, leaving a sad-

EXPLANATION OF PLATE 82

FIGS. *1,2*—*Pseudoschistoceras gigas* (Smith). Uni. W. A. hypotype 18105, ×1, from the Lower Permian (Baigendzhinian) Bitauni beds, Timor.



TEXT-FIG. 3—Diagrammatic representations of external sutures of *Propinacoceras*.
A. *P. australe* Teichert. From the Lower Permian Wandagee Formation, Carnarvon Basin, Western Australia; based on Bur. Min. Res. C.P.C. hypotype 1763, at a conch diameter of 55 mm.
B. *P. simile* Haniel. From the Lower Permian (Baigendzhinian) Bitauni beds of Timor; an "ausgewachsenen Windung" (from Haniel, 1915, p. 35, fig. 5a).

dle across the umbilicus. The ventral flank of the first lateral saddle is undivided, whereas mature specimens exhibit two rounded asymmetric adventitious subdivisions on the adoral portion of the first lateral saddle and an adorally constricted bifid adventitious lobe on the dorsal flank of the saddle. At least the first nine external lateral lobes are strongly bifid and are conspicuously inflated at about their mid-height; most of them are considerably modified in shape where they come into contact with the saddles of the preceding septum. None of the available specimens shows whether the tenth external lateral lobe is simple or bifid. The second lateral lobe is much deeper than the corresponding first lateral. The dorsolateral lobes are probably simple, but their apices are not discernible in any of the available specimens.

Discussion.—Additional collections, not available to the original author of this species, allow greater precision in the representation of the suture. Text-figure 3A is drawn from Bur. Min. Res. C.P.C. hypotype 1763, a specimen of almost exactly the same size as the holotype. This hypotype is generally better preserved than the holotype, but in all observable features the sutures of the two specimens are virtually identical. Study of the holotype shows that, as in the hypotype, the adventitious lobe on the dorsal flank of the first lateral saddle is bifid and not entire. In addition, there are two adventitious lobes on the adoral flank of the first lateral saddle, and these two lobes are approximately equal in depth. There is no evidence from the holotype to suggest that the seventh and eighth external lateral lobes are entire rather than bifid.

Text-figure 3A shows nine pairs of lateral

TABLE 4—DIMENSIONS (IN MM.) AND PROPORTIONS OF *Propinacoceras australe* TEICHERT

	D	H	W	U	H/D	W/D	U/D
holotype 20145	60.5	37.5	17.5	1.5	.62	.29	.02
hypotype 1763	60	37	17	1.5	.62	.28	.02
figd. spec. 20509	6.9	2.9	1.8	2.1	.42	.26	.30

lobes in the external suture. However, Bur. Min. Res. C.P.C. hypotype 1764 develops ten pairs of external lateral lobes at a considerably smaller shell diameter than that of the figured hypotype. Consequently, it seems that at least one additional lobe is concealed across the umbilical shoulder of the hypotype from which Text-figure 3A was constructed.

A poorly preserved phragmocone (Uni. W.A. 2555) from the basal Liveringa Formation of the Fitzroy Basin almost certainly belongs in *Propinacoceras australe*. The transversely elongate nodes across the ventrolateral shoulders and the available portions of the suture are practically identical with those of similarly sized specimens (approximately 60 mm. conch diameter) from the Carnarvon Basin.

Comparisons.—Ruzhencev (1956, p. 97) divided the known species of *Propinacoceras* into three groups. Sutural studies show that *P. australe* should be included in the group of *P. knighti* Miller & Furnish (1940, p. 42–44, pl. 5, figs. 1–4, pl. 6, fig. 7), which is apparently restricted to the Leonardian (Baigendzhinian Substage). The group includes *P. knighti* from the Leonard and Bone Spring formations and the San Andres Group of Texas, *P. bornemani* Toumansky & Borneman (1937, p. 108) and possibly *P. darwasi* Karpinsky from the Artinskian sediments of Bukhara (middle Asia), and *P. simile* Haniel (1915, p. 34–39) from the Bitauni beds of Timor. *P. australe* resembles *P. simile* in the development of a bifid adventitious subdivision on the dorsal flank of the first lateral saddle, but it differs from all other known species of the genus by combining this bifid adventitious lobe with external lateral lobes which are all bifid in mature whorls.

Occurrence.—Uni. W.A. holotype 20145 is from the same horizon as *Helicoprion davisii* and *Paragastrioceras wandageense* (Teichert, 1952, p. 130), on the west limb of the syncline north of Wandagee Hill, 1475 yards north of the Wandagee-Minilya road, in the Coolkilya Paddock of Wandagee Station, Carnarvon Basin, Western Australia. It came from not more than 100 feet above the base of the Coolkilya Greywacke, a formation of the Kennedy Group which was known previously as the "*Linoproductus* stage of the Wandagee series." Teichert (1942, p. 226) recorded one other specimen from the same horizon as the holotype, and all additional material in his collection (including figured specimens 20144b, 20509, 20510 and specimen 20144a) came from the "*Calceolispongia* stage of the Wandagee series," now known as the Wandagee Formation of the Byro Group. All Teichert's specimens were collected in the Coolkilya Paddock of Wandagee Station. Teichert's subsequent report (1952, p. 117) of the occurrence of this species near the top of the Coolkilya Greywacke has not been substantiated.

New collections include more material from the Wandagee Formation. Bur. Min. Res. C.P.C. hypotype 1763 and specimen F.21628 came from a point 1.5 miles on a bearing of 52° from Curdamuda Well and 2.6 miles on a bearing of 278° from Cundlego Well, at 23° 44′ 06″ S., 114° 24′ 49″ E. on Wandagee Station in the Carnarvon Basin of Western Australia. Hypotype 1763 was found at approximately 300 feet above the base and specimen F.21628 at 190 feet above the base of the Wandagee Formation. Uni. W.A. specimen 23237 is recorded as coming from the Quinnanie Shale near Coolkilya Pool, on the south bank of the Minilya River. Bur. Min. Res. C.P.C. hypotype 1764 came from 136 feet below the top of the Bulgadoo Shale at a point 2.0 miles on a bearing of 151° from Donelly's Well, at 24° 05′ 03″ S., 115° 05′ 36″ E. An even lower horizon for *P. australe* is known from several specimens (Bur. Min. Res. F.21629 A–D) collected from near the base of the Bulgadoo Shale. The locality is 7.6 miles on a bearing of 231° from Moogooloo Trig. (K58), at 23° 38′ 42″ S., 114° 38′ 33″ E., on Wandagee Station close to the Wandagee-Middalya Station boundary, in the Carnarvon Basin of Western Australia.

Uni. W.A. specimen 2555 was collected in 1922; it was identified on the original label as a ganoid fish. The specimen was listed as having come from a "well at Selection Homestead, probably five miles north by east from Survey Station C.44 [18° 59′ 33″ S., 125° 54′ 34″ E., see Western Australia Lands and Surveys Litho. 129/300], Christmas Creek, in the lower Liveringa." Selection Homestead is now known as Christmas

Creek Homestead, and there is no reasonable doubt that the specimen came from the exposures of the lower Liveringa Formation or the upper Noonkanbah Formation which are known to occur to the northeast of this Homestead in the vicinity of Fig Tree Bore. J. M. Dickins determined the poorly preserved invertebrates associated with the ammonoid as *Streblochondria* sp., Bellerophontidae gen. et sp. indet. and *Warthia* cf. *W. micromphala* (Morris) and believes it most likely that they were derived from the lower Liveringa Formation, although possibly they could have come from the upper Noonkanbah Formation.

All occurrences of *P. australe* are assumed to be of Baigendzhinian (late Artinskian) age.

Respository.—Holotype 20145 and figured specimens 20509, 20510 and 20144 are lodged with the Department of Geology of The University of Western Australia, and hypotypes 1763 and 1764 and specimens F.21628, F.21629 A–D with the Commonwealth of Australia Bureau of Mineral Resources, Canberra.

PROPINACOCERAS n. sp.
Pl. 78, figs. 14,15; text-fig. 4

Description.—Two fragmentary specimens in the authors' collections are referable to a new species of *Propinacoceras*. Both specimens include portions of the living chamber, and one of them retains part of the phragmocone. The conch is discoidal and the flanks are flattened and almost parallel. A median groove traverses the flattened venter and is bounded by two rows of nodes on the ventrolateral shoulders. These nodes show only a slight tendency towards transverse elongation.

Only the ventral and first lateral lobes and the first and second lateral saddles are preserved. The ventral lobe is narrowly trifid. The ventral flank of the first lateral saddle is undivided, but three adventitious subdivisions appear on the adoral flank of this saddle, and the dorsal flank is divided by a deep asymmetric adventitious lobe. The first lateral lobe is prominently bifid and of slightly greater depth than the ventral lobe. The relative depth of the second lateral lobe can not be determined with certainty, but it seems probable that this lobe was somewhat deeper than the corresponding first lateral lobe.

TEXT-FIG. 4—Diagrammatic representation of part of the suture of *Propinacoceras* n. sp., from the Lower Permian Coyrie Formation, Carnarvon Basin, Western Australia; based on Bur. Min. Res. C.P.C. figured specimen 1765, at a conch diameter of approximately 12 mm.

Comparisons.—Although only a fraction of the suture is discernible, there is no doubt that the species belongs in *Propinacoceras*, as this is the only advanced medlicottiid in which the ventral flank of the first lateral saddle is undivided. *Propinacoceras* n. sp. has a divided dorsal flank of the first external lateral saddle, and consequently belongs in the group of *P. knighti* (Ruzhencev, 1956, p. 97). It differs from most species of the genus in developing three instead of two adventitious subdivisions on the crest of the first lateral saddle, but is similar in this respect to some of the specimens of *P. simile* (Haniel, 1915, p. 35, fig. 5b) from the Bitauni beds of Timor. The nodes across the ventrolateral shoulder of *P. simile* are transversely elongate, whereas they are rounded in *P.* n. sp. *P. australe* differs in developing two adventitious subdivisions across the crest of the first lateral saddle, and it has transversely elongate nodes across the ventrolateral shoulder.

P. rhipaeum Ruzhencev (1956, p. 101–104, pl. 2, figs. 3–5), from the Aktastinian (early Artinskian) of the Southern Urals resembles *P.* n. sp. in the development of a broad ventral lobe and rounded nodes on the ventrolateral shoulder. The relative depths of the first and second lateral lobes can not be determined in the Australian species.

Occurrence.—Both representatives (Bur. Min. Res. C.P.C. figured specimen 1765 and specimen F.21627) are from 4.95 miles on a bearing of 119° from Donelly's Well, and 4.7 miles on a bearing of 236° from

Moogooree Homestead, at 24° 06′ 06″ S., 115° 08′ 04″ E., on Moogooree Station in the Carnarvon Basin of Western Australia. They were collected from 485 feet above the base of the Coyrie Formation, where they were associated with a varied marine fauna (Condon, 1954, p. 63). *Neocrimites* sp. is also found in the Coyrie Formation, and ammonoid studies suggest that this unit should be correlated with either the early Baigendzhinian Substage or Aktastinian Substage of the Lower Permian Artinskian Stage.

Repository.—Figured specimen 1765 and specimen F.21627 are lodged with the Commonwealth of Australia Bureau of Mineral Resources, Canberra.

Family AGATHICERATIDAE Arthaber, 1911

Only two genera are referred to the Agathiceratidae. *Agathiceras* Gemmellaro (1887) is geographically widespread and locally very abundant in beds ranging in age from Lower Pennsylvanian to early Guadalupian. A detailed discussion of the genus and its proposed subgenera is given below under the generic heading. *Proshumardites* Rauser (1928), the more primitive member of the family, is fairly common in the early Upper Carboniferous sediments of middle Asia, the Urals, Spain, North Africa, and Oklahoma.

The systematics of the Agathiceratidae have been considered exhaustively by such authors as Gemmellaro (1888), Schindewolf (1931), Böhmers (1936), Miller & Furnish (1939), and Ruzhencev (1950b). No further discussion is necessary in the present work.

Genus AGATHICERAS Gemmellaro, 1887

Type species.—*Agathiceras Suessi* Gemmellaro, 1887, p. 79, pl. 6, figs. 1-4.

Agathiceras is the most abundant ammonoid in the Sosio Limestone, and we have some 200 Sicilian representatives available for study. It is equally abundant in the Permian of West Texas and Coahuila. Haniel had over 500 specimens from Timor, and Ruzhencev reported over 2000 specimens from the Urals.

All the variously named species of *Agathiceras* are more closely similar to each other than is usual in comparable Permian ammonoid taxa. Middle and Upper Pennsylvanian representatives of the genus are essentially identical to Permian species. Such a stable biologic group may nevertheless be expected to show some variation within a single biota. Sosio specimens exhibit gradational differences in the form of the conch, and nearly 300 per cent variation in the diameter attained at full maturity; Haniel (1915, p. 66–72) likewise noted the variable nature of the conch in *A. sundaicum.*

Diagnosis.—Shell involute, generally ellipsoidal in cross-section, but may be parabolic or circular. Longitudinal lirae usually prominent, but shell may be smooth except for delicate transverse growth lamellae. Suture consists of a broadly bifid ventral lobe, three pairs of subequal spatulate lateral lobes, a pair of shallow rounded lobes across umbilicus, a pair of narrow V-shaped dorsolateral lobes and a deep V-shaped dorsal lobe. Sutural formula:

$$(V_1V_1)L_2L_1L_2U{:}ID$$

Siphuncle central in early growth stages but later becomes ventral. Septal necks retrochoanitic and exceptionally long.

Distribution.—Most of the known species of *Agathiceras* and their distributions have been listed by Ruzhencev (1950b, p. 93).

Discussion.—*Gaetanoceras* was proposed by Ruzhencev (1938, p. 262) as a subgenus of *Agathiceras*, with *A. martini* Haniel (1915, p. 72–74, pl. 49, figs. 18,19) as type species. It is similar to the subgenus *Agathiceras* in both shell form and suture pattern but differs in lacking longitudinal lirae and in the development of slightly stronger transverse growth lamellae. Only the one species has been referred to *Caetanoceras*, although Gerth (1950, p. 255) elevated to full specific rank a variety described from Timor by Haniel as *A. martini* var. *globosa*. Gerth recorded *A. martini* from the Bitauni and Taë Wei beds and *A. globosum* from the Basleo beds of Timor. These forms may represent an extreme variant, as they are found as relatively few specimens in association with hundreds of *A. sundaicum*. Also, the ontogeny of *A. martini* is not yet known. It is difficult therefore to justify the retention of *Gaetanoceras* as a valid subgenus.

Paragathiceras Ruzhencev (1950b, p. 92) was later erected as a subgenus of *Agathi-*

ceras to include forms which are similar to the subgenus *Agathiceras* in sculpture and sutural pattern but differ in the development of a parabolic instead of an ellipsoidal cross-section. The type species is *Agathiceras*(?) *tornatum* Gemmellaro (1887, pl. 6, figs. 5-7) from the Sosio Limestone of Sicily. Ruzhencev doubtfully referred a Timorian specimen figured by Haniel (1915, pl. 49, figs. 13a-c) to Gemmellaro's species. This same specimen had been included earlier in the Australian species, *Agathiceras applanatum* (Teichert, 1944, p. 87). The two forms are certainly comparable in ornamentation, cross-section and suture, and are probably closely related. However, insufficient information is available to establish specific identity.

Miller & Furnish (1957b, p. 51) do not recognize the validity of *Paragathiceras* and in our present state of knowledge, the taxon seems to be of dubious value.

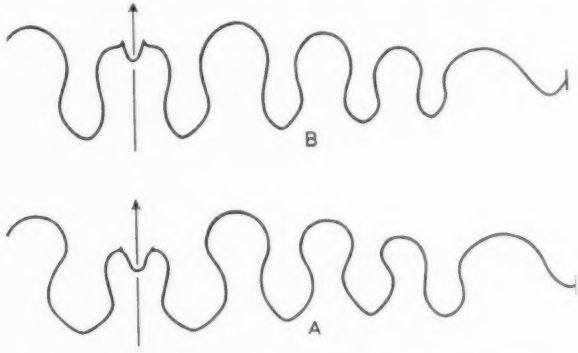
Agathiceras has been recorded many times from the "Permo-Carboniferous" of Australia, but Teichert & Fletcher (1943) demonstrated that all previous references to *Agathiceras* in the late Paleozoic of Australia were based on misidentifications. The holotype of *A. applanatum* is the only known representative of the genus in either the Carboniferous or the Permian of Australia.

AGATHICERAS APPLANATUM Teichert, 1944
Pl. 80, figs. 6,7; text-fig. 5A

Agathiceras applanatum TEICHERT, 1944, Jour. Paleontology, v. 18, p. 85–87, pl. 17, figs. 6,7, text-fig. 1.

Description.—The holotype is the only known representative of this species. It is a fairly well preserved conch which retains part of the shell and one-quarter of a volution of living chamber. The conch is involute and thickly lenticular in cross-section, with gently convex flanks and a narrowly curved venter. Dimensions are: maximum conch diameter, 19 mm.; maximum whorl height, 11½ mm.; maximum width, 9½ mm.; umbilical diameter, 1 mm. Traces of prominent, regular, evenly spaced, longitudinal lirae cover the shell. These lirae are one-third of a mm. apart across the flanks of the living chamber. Constrictions and growth lamellae are not apparent.

The external suture consists of a prominently bifid ventral lobe, three lateral lobes, and a broadly rounded umbilical lobe centered just outside the line of involution. The secondary ventral saddle is about three-quarters the height of the first lateral saddle, and the prongs of the ventral lobe are much wider than the lateral lobes. A regular decrease in the height of the lateral saddles takes place from the first through



TEXT-FIG. 5—Diagrammatic representations of external sutures of *Agathiceras*.
A. *A. applanatum* Teichert. From the Upper Permian section of the Coolkilya Greywacke, Carnarvon Basin, Western Australia; based on Uni. W. A. holotype 21451, at a conch diameter of 15 mm.
B. *A. uralicum* (Karpinsky). From the Artinskian sediments of the Ural Mountains; based on State Uni. Iowa hypotype 1387, at a conch diameter of approximately 12 mm. (from Miller & Furnish, 1939, p. 299, fig. 2E).

the second to the third. The third lateral saddle is conspicuously asymmetric and the third lateral lobe is not as narrowly rounded as the other laterals. An unusually broad rounded saddle traverses the umbilical shoulder and the adjacent area of the flanks. The septal necks are retrochoanitic and attain a length of 2 mm., which is approximately equal to the height of the corresponding first lateral saddle.

Comparisons.—Ruzhencev (1950b, p. 92) drew attention to the difficulty encountered in differentiating species of *Agathiceras*. This difficulty results from the unusual stability of the genus throughout an extensive period of geologic time. Undoubtedly, more species of *Agathiceras* have been recognized than is warranted by known variations in morphology, and many of the species are inadequately described. Satisfactory sutures cannot be obtained from much of the older literature, and comparisons must be confined largely to the shell cross-section and ornamentation.

The proportions of whorl height to whorl width and to conch diameter of *Agathiceras applanatum* are almost identical with those of several Permian species of the genus, including the type, *A. suessi* Gemmellaro (1887, pl. 6, figs. 1–4). However, the Australian form appears to possess a subparabolic cross-section rather than the ellipsoidal section of most other representatives of the genus. It resembles *A.? tornatum* Gemmellaro (1887, pl. 6, figs. 5-7) in this latter respect, but differs from the Sicilian species in the development of exceptionally broad prongs of the ventral lobe. Perhaps this combination of parabolic section and exceptionally broad prongs of the ventral lobe will permit continued recognition of the species. However, better preserved specimens of *A. applanatum* must be obtained before the independence of this taxon can be maintained with confidence.

A small specimen figured by Haniel (1915, pl. 49, fig. 13), from between Soefa and Manoemea in Timor, may possibly belong in *A. applanatum* (Teichert, 1944, p. 87). However, the specific affinities of the Timorian specimen may not become apparent until the ontogeny of the Australian species has been established from well preserved specimens.

Occurrence.—The only known specimen of this species came from 300 yards east of the mouth of the southeastern gully of Wandagee Hill (23° 50½′ S., 114° 27½′ E.) in the Mungadan Paddock of Wandagee Station, Carnarvon Basin, Western Australia. It is from about 90 feet below the top of the Coolkilya Greywacke (Teichert, 1952, p. 130), where it is associated with *Pseudogastrioceras goochi*. Ammonoid studies suggest that the Baigendzhinian-Wordian boundary passes through the Coolkilya Greywacke and that the beds which yielded *A. applanatum* are of early Guadalupian age.

Repository.—Holotype 21451 is lodged with the Department of Geology of The University of Western Australia.

Family THALASSOCERATIDAE Hyatt, 1900

The phylogeny and systematics of the Thalassoceratidae have been considered in several monographic works (Miller & Furnish, 1940, p. 104–107; Ruzhencev, 1950b, p. 103–114; 1952, p. 58–62). This family represents a closely knit phylogenetic unit in strata ranging from Viséan to lower Guadalupian age. Several trends can be traced throughout the development of the family, but no single phylogenetic trait is sufficiently consistent to serve alone as a basis for generic differentiation.

Thalassoceras Gemmellaro, 1887 (type: *T. Phillipsi* Gemmellaro, 1887, SD) characteristically has strongly serrate lobes, in which the larger individual subdivisions constitute almost half the total lobe depth at maturity. Secondary dissection of the mature suture of *Thalassoceras* extends from the base of the lobes to about three-fourths the total height to the crest of the lateral saddle. The genus is widely distributed but rare in strata ranging in age from Sakmarian to early Guadalupian. It has not been reported from the Asselian, but *Prothalassoceras bashkiricum* Ruzhencev (1950b, p. 113–114, pl. 4, fig. 10), which is common in the late Pennsylvanian (Orenburgian) of the Southern Urals, should possibly be included in *Thalassoceras*.

Prothalassoceras Böse, 1919 (type: *P. Welleri* Böse, 1919, OD) was proposed for a more primitive species in which the lobes are irregularly serrate. The individual serra-

tions are typically only about one-fourth the depth of the entire lobe, and they extend for about two-thirds the height to the crest of the saddle. *Thalassoceras* and *Prothalassoceras* are gradational; the generic assignment of some species must remain uncertain if both taxa are retained. *Prothalassoceras*, according to our interpretation, would include only a few forms from the Lower Permian (Asselian and Sakmarian stages). Ruzhencev (1950b, p. 109–114) referred several late Pennsylvanian species to the genus. However, *P. inflatum* Ruzhencev is closely similar to the type of *Eothalassoceras; P. jaikense* Ruzhencev is better referred to *Eothalassoceras*, although it is somewhat transitional between this genus and *Prothalassoceras;* and *P. bashkiricum* Ruzhencev is probably a primitive *Thalassoceras*.

Difficulty may also occur in differentiating *Prothalassoceras* from the still more primitive genus *Eothalassoceras* Miller & Furnish, 1940 (type: *Prothalassoceras inexpectans* Miller & Owen, 1937, OD). Characteristically, *Eothalassoceras* possesses sutures in which the serrations are extremely irregular. These secondary subdivisions occupy a relatively smaller part of the lobe, as they extend only about one-third the height to the crest of the saddle. *Eothalassoceras* is typically developed and common in the Upper Pennsylvanian (Missourian and Virgilian), but *Thalassoceras biforme* Gerassimov (Ruzhencev, 1951, p. 103–104, pl. 6, fig. 7) from the Asselian of the Southern Urals should probably be included in the genus. *E. aurorale* Gordon (1957, p. 54–55, pl. 3, figs. 16–19) from strata of late Viséan age in Alaska is the oldest known representative of the genus.

Gleboceras Ruzhencev, 1950b (type: *G. mirandum* Ruzhencev, 1950, OD) was proposed for an ancestral thalassoceratid which differs from *Eothalassoceras* in possessing narrow undivided prongs of the mature ventral lobe. *Gleboceras* is known from the early Upper Pennsylvanian (Zhigulian or Missourian Stage) of the Southern Urals.

Aristoceras Ruzhencev, 1940 (type: *A. chkalovi* Ruzhencev, 1940, OD) is typically similar to *Eothalassoceras* in sutural contours, but the conch is more nearly discoidal and the growth lamellae are more strongly sigmoidal. The prominent narrow ventrolateral salient in the growth lines is associated with one or two longitudinal furrows. Cumulatively, these shell features appear quite distinct, but our experience suggests that they are too inconsistent to be credited with major taxonomic status. *Aristoceras* has been found in abundance in the Upper Pennsylvanian (Zhigulian and Orenburgian stages). Forms which possess the prominent ventrolateral grooves have been noted in younger strata; they are otherwise identical with associated thalassoceratids without the grooves. *Eothalassoceras keytei* (Smith, 1929, p. 76, figs. B,14-16) of the Gaptank Formation of West Texas, *E. caddoense* (Plummer & Scott, 1937, p. 355–356, pl. 36, figs. 4-6) from the Graham Formation of Central Texas, and *Thalassoceras varicosum* Gemmellaro (1887, p. 72–73, pl. 5, figs. 20–22; pl. 7, figs. 33,34) from the Sosio Limestone of Sicily all exhibit this characteristic shell feature but should not be associated with type *Aristoceras*.

EXPLANATION OF PLATE 83

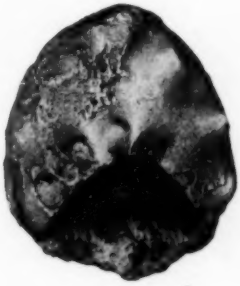
FIGS. *1–6*—*Pseudoschistoceras simile* Teichert, from the Lower Permian Barrabiddy Member of the Bulgadoo Shale, Carnarvon Basin, Western Australia. *1–3*, Uni. W. A. paratype 21440, ×1; *4*, Uni. W. A. holotype 21326, ×1; *5,6* Uni. W. A. paratype 21328, ×1.

7,8—*Neocrimites* sp. Modelling clay cast of Bur. Min. Res. C.P.C. figured specimen 1777, ×3, from the Lower Permian Coyrie Formation, Carnarvon Basin, Western Australia (see also pl. 86, figs. 4,5).

9—*Metalegoceras* n. sp. Bur. Min. Res. C.P.C. figured specimen 1770, ×$\frac{3}{4}$, from the Lower Permian Callytharra Formation, Carnarvon Basin, Western Australia.

10—*Popanoceras* sp. indet. Bur. Min. Res. C.P.C. figured specimen 1775, ×1$\frac{1}{2}$, from the Upper Permian part of the Coolkilya Greywacke, Carnarvon Basin, Western Australia.

1

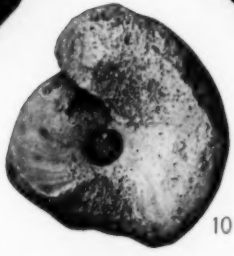

2

3

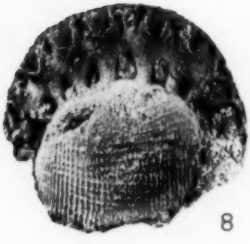
7

4

9


10

5


8

6

1

2

5

6

7

3

4

8

11

10

9

Delepinoceras Miller & Furnish, 1954 (type: *Dimorphoceras thalassoide* Delépine, *in* Delépine & Menchikoff, 1937, OD) is a primitive member of the family in which the prongs of the ventral lobe and the lateral lobes are uniformly trifid. It has been recorded from the Namurian of the Pyrenees and North Africa, the Lower Namurian of the Southern Urals, and is known from the Springerian of Oklahoma. The trifid lobes of *Delepinoceras* are regarded as having familial significance by Ruzhencev (1957, p. 58).

Yinoceras Chao, 1954 (type: *Y. lenticulare* Chao, 1954, OD) is an unusual thalassoceratid from the Permian (Probably Artinskian) of Hunan. It is characterized by an acute venter and ribbed test. This genus must be considered as being imperfectly known until additional study material is available.

Epithalassoceras Miller & Furnish, 1940 (type: *E. ruzhencevi* Miller & Furnish, 1940, OD) is the most advanced thalassoceratid yet known. It is characterized by regular lanceolate sutural subdivisions which extend nearly to the crest of the lateral saddle. Two additional features, the relatively small size of the secondary ventral saddle and bifid nature of the dorsal lobe, serve to distinguish this genus from its predecessors. *Epithalassoceras* is based on a single specimen from the lower Guadalupian of Coahuila.

Genus THALASSOCERAS Gemmellaro, 1887

Type species.—*Thalassoceras Phillipsi* Gemmellaro, 1887, p. 69, pl. 10, figs. 13,14.

Discussion.—The systematics and distribution of *Thalassoceras* have been considered under the familial heading. Additional information is available in publications by Miller & Furnish (1940, p. 104–105) and Ruzhencev (1950b, p. 105–107; 1956, p. 123–129). The sutural formula is:

$$(V_1V_1)LU:ID$$

THALASSOCERAS WADEI Miller, 1936

Pl. 78, figs. 1-5; text-figs. 6,7

Thalassoceras wadei MILLER, 1936, Jour. Paleontology, v. 10, p. 685–687, pl. 92, figs. 8–12; TEICHERT, 1942, Jour. Paleontology, v. 16, p. 231, pl. 35, fig. 11, text-fig. 7.

Discussion.—Miller's original description was based on two immature specimens. The discovery of a fragment of a larger phragmocone (Uni. W.A. hypotype 20143) allowed Teichert (1942, p. 231, fig. 7) to figure part of the mature suture of this species. One additional fragment of a phragmocone was collected recently by geologists of the Bureau of Mineral Resources, but this specimen does not add appreciably to our knowledge of the species. Nothing can be appended to Miller's original description, but a more nearly accurate representation of the suture of the hypotype figured by Teichert is given in Text-figure 7.

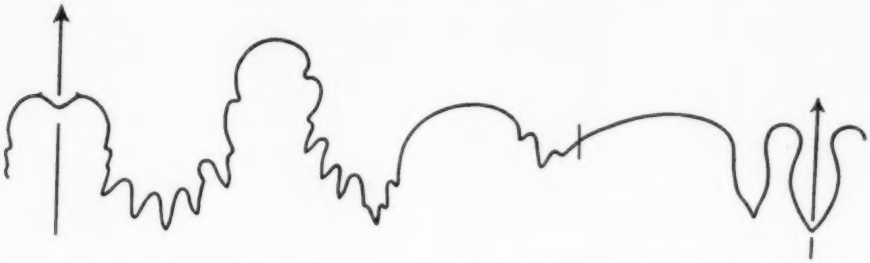
Comparisons.—Significant sutural modifications take place during the ontogeny of species of *Thalassoceras*, and commonly a single suture is strikingly asymmetric (Ruzhencev, 1951, text-fig. 29). The four available representatives of *T. wadei* give only the most rudimentary picture of the ontogeny of that species. Consequently, useful comparisons of the sutural details of the Australian species can not be drawn.

EXPLANATION OF PLATE 84

FIGS. *1–4*—*Pseudogastrioceras goochi* Teichert. *1,2*, Bur. Min. Res. C.P.C. hypotype 1772, ×3, from the Upper Permian Lightjack Member of the Liveringa Formation, Fitzroy Basin, Western Australia; *3,4*, Uni. W. A. holotype 20504, ×1, from the Upper Permian part of the Coolkilya Greywacke, Carnarvon Basin, Western Australia (see also pl. 85, figs. 1,2,5–7).

5–7—*Paragastrioceras wandageense* Teichert, Uni. W. A. holotype 20142, ×1¼, from the Lower Permian part of the Coolkilya Greywacke, Carnarvon Basin, Western Australia.

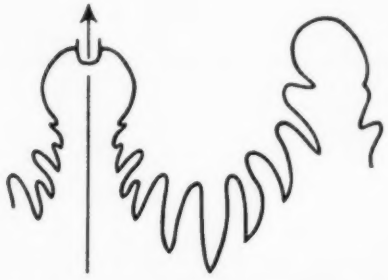
8–11—*Uraloceras irwinense* Teichert & Glenister, from the Lower Permian Holmwood Shale, Perth Basin, Western Australia. *8,9*, Uni. W. A. paratype 32037, ×3; *10*, Uni. W. A. holotype 32036, ×2; *11*, Uni. W. A. paratype 32040, ×3.



TEXT-FIG. 6—Diagrammatic representation of the suture of *Thalassoceras wadei* Miller, from the Lower Permian Nura Nura Member of the Poole Sandstone, Fitzroy Basin, Western Australia; based primarily on Uni. W. A. syntypes 19987, 19988, at a conch diameter of approximately 11 mm.

The subdivisions of the primary saddles and lobes in *T. wadei* are more complex than those of *Prothalassoceras*, and the internal lateral lobes are undivided, and not bifid as in *Epithalassoceras*.

Occurrence.—All known occurrences of this species are from the Nura Nura Member of the Poole Sandstone, of uppermost Sakmarian age, in the Nura Nura Ridge area of the Fitzroy Basin of Western Australia. Uni. W.A. Syntypes 19987, 19988 are from 3 miles east of Nura Nura Outcamp; Uni. W.A. hypotype 20143 is from about 1½ miles east of Nura Nura Outcamp, and Bur. Min. Res. C.P.C. hypotype 1766 is from 1.6 miles southwest of Paradise Homestead, at 18° 02½′ S., 124° 31′ E. *T. wadei* is found in association with *Metalegoceras clarkei*, *M. striatum*, *Propopanoceras ruzhencevi*, and gen. indet.



TEXT-FIG. 7—Diagrammatic representation of part of the mature suture of *Thalassoceras wadei* Miller, from the Lower Permian Nura Nura Member of the Poole Sandstone, Fitzroy Basin, Western Australia; based on Uni. W. A. hypotype 20143, a fragment with a whorl width of approximately 18 mm.

Repository.—Syntypes 19987 and 19988 and hypotype 20143 are lodged with the Department of Geology, The University of Western Australia, and hypotype 1766 and specimen F.21626 with the Commonwealth of Australia Bureau of Mineral Resources, Canberra.

Family METALEGOCERATIDAE Plummer & Scott, 1937

This taxon was erected to include *Metalegoceras*, *Pseudogastrioceras*, *Eothinites*, *Glaphyrites* and *Cravenoceras*. However, detailed studies have shown that all these forms are not closely related. *Metalegoceras* Schindewolf (1931) and *Eothinites* Ruzhencev (1933) are genera which are still retained in the Metalegoceratidae. To them can be added *Juresanites* Maximova (1940), *Pseudoschistoceras* Teichert (1944) and *Spirolegoceras* Miller, Furnish & Clark (1957). A direct phylogenetic sequence can be traced from *Juresanites* through *Metalegoceras* to *Pseudoschistoceras* but the positions of *Eothinites* and *Spirolegoceras* within the family are uncertain.

Juresanites is known from the Asselian Stage and the early Sakmarian Stage of the Ural Mountains, and from beds of presumed similar age (Holmwood Shale) in the Irwin River District of Western Australia.

Metalegoceras evolved directly from *Juresanites*, and transitional species of uncertain generic assignment are known. The

genus probably does not extend down into the Asselian, but it is common in the early Sakmarian Stage, and in the Artinskian of the Ural Mountains, Oman, southwestern United States, Timor, and Western Australia.

Oyens (1938, p. 1123, 1124) and Gerth (1950, p. 248) identified *Metalegoceras* from the Taë Wei fauna of Timor, and Gerth referred this fauna to the *Waagenoceras* Zone of early Guadalupian age. However, many of the elements from the Taë Wei fauna are common to the Bitauni beds and therefore suggest an Artinskian age for the parent strata. The only evidence for a younger age stems from the forms identified by Gerth as "*Prohyattoceras*" n. sp. and *Waagenoceras oyensi*. These two species are actually primitive representatives of *Hyattoceras* (Ruzhencev, 1956, p. 35–36), a genus which is otherwise restricted to the Guadalupian. The information above has been regarded as an indication that *Metalegoceras* extends into the Guadalupian; but the weight of overall evidence suggests rather that *Hyattoceras* appeared in the late Artinskian and that *Metalegoceras* is an exclusively Lower Permian genus.

Few of the younger metalegoceratids from Timor have received the detailed sutural studies required in modern ammonoid taxonomy, although their preservation is conducive to such investigations. At least some of the Timorian species now referred to *Metalegoceras* should be placed in *Pseudoschistoceras*.

Eothinites is widespread geographically but is restricted to strata of Artinskian age. The genus has been reported (Ruzhencev, 1956, p. 197–209) to occur abundantly in both the Aktastinian and Baigendzhinian substages of the Southern Urals. Other occurrences are known from strata of similar age in middle Asia, Timor and Texas.

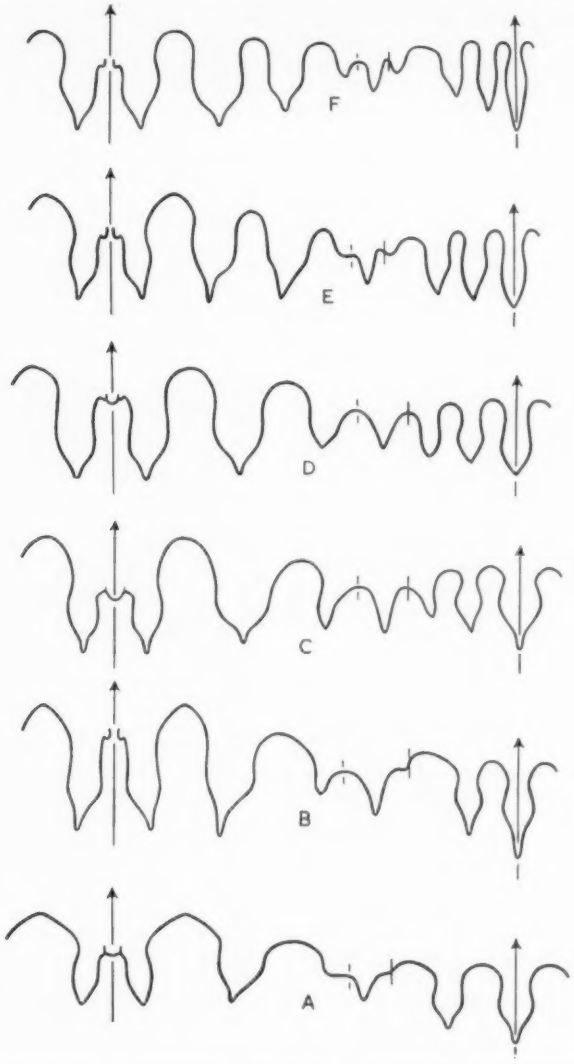
Pseudoschistoceras is known from the Baigendzhinian Barrabiddy Member of the Bulgadoo Shale in the Carnarvon Basin of Western Australia, and from the Bitauni Beds of Timor. *P. gigas* (Smith) is the only Timorian species known at present, but sutural studies of the Timor material might well place other species in this genus.

Spirolegoceras was described from the Meade Peak Member of the Phosphoria Formation in Idaho. This occurrence is believed to be of Baigendzhinian age. *Metalegoceras* sp. of Harker (*in* Harker & Thorsteinsson, 1960, p. 77, pl. 25, figs. 4–6) from Arctic Canada is probably congeneric.

The phylogeny and systematics of the Metalegoceratidae were considered in detail, by Ruzhencev (1951, 1952, 1956). The lobes in the vicinity of the umbilicus are of the greatest value in tracing the phylogeny of the family and in separating the component genera and species (Text-fig. 8).

Juresanites Maximova (1940, p. 859) is the most primitive representative of the Metalegoceratidae. Its type species, *J. primitivus* Maximova (1940, p. 860), is known from the late Asselian of the Urezan and Aktyubinsk areas of the Ural Mountains. This form develops a total of 12 primary lobes in the mature suture. However, the lobes which occur on either side of the primary umbilical lobe are shallow; this is particularly true of the incipient lobe which occurs on the umbilical wall near the line of involution. The presence of this incipient lobe in the mature external suture is the most diagnostic single feature of *Juresanites*, as it allows the presence of only one pair of dorsolateral lobes. The shallowness of the lobes on either side of the umbilical lobe also separates *Juresanites* from other members of the family. *Juresanites* is represented by an additional species, *J. kazakhorum* Ruzhencev (1952, p. 68–71), from the Aktyubinsk region of the Urals, and by *J. jacksoni* (Etheridge, 1907, p. 36–37) and *J. campbelli* (Teichert & Glenister, 1952, p. 18–20) from the Holmwood Shale of the Irwin River District of Western Australia (Text-figs. 8A,B). *J. kazakhorum* is from the early Sakmarian Stage, and the Western Australian species are assumed to be the same age.

Species of *Metalegoceras* also have 12 primary lobes in mature specimens (Text-figs. 8C,D), but they can be differentiated from species of *Juresanites* in both the degree of development and the position of the lobes which form, during ontogeny, by tripartition of the primary umbilical lobe. The incipient lobe, which lies in the mature external suture of *Juresanites* close to the line of involution, migrates inward during the ontogeny of *Metalegoceras* to form a



TEXT-FIG. 8—Diagrammatic representations of sutures of *Juresanites*, *Metalegoceras* and *Pseudoschistoceras*.

A. *J. campbelli* (Teichert & Glenister). From the Lower Permian Holmwood Shale, Perth Basin, Western Australia; based on Uni. W. A. paratype 32031, at a conch diameter of approximately 12 mm.

B. *J. jacksoni* (Etheridge). From the Lower Permian Beckett Member of the Holmwood Shale, Perth Basin, Western Australia; based on Uni. W. A. hypotype 37512, at a conch diameter of 95 mm.

deep second dorsolateral lobe. Consequently this lobe lies on the external suture of species of *Juresanites* and on the internal suture of mature *Metalegoceras*. This migration takes place at a late ontogenetic stage in primitive Sakmarian species of *Metalegoceras* and at an earlier growth stage in more advanced Artinskian species. Differences in the shape and relative depth of the three lobes which result from tripartition of the primary umbilical lobe also allow separation of the two genera, although somewhat transitional forms are known. The lobes on either side of the umbilical lobe in the four known species of *Juresanites* are shallower than the corresponding umbilical lobes. These same lobes are relatively deeper in Sakmarian species of *Metalegoceras*, but they rarely exceed the depth of the corresponding umbilical lobe. Similarly, in some Artinskian species of *Metalegoceras*, the lengths of the second internal lateral and the second external lateral lobes are slightly less or approximately equal to the length of the corresponding umbilical lobe. However, in most Artinskian species, including the holotype *M. evolutum* (Haniel, 1915, p. 60–64), the umbilical lobe is the shortest lobe in the mature suture. Interspecific variation in the form and sculpture of the conch is marked in *Metalegoceras*.

Two additional pairs of lobes are formed in *Pseudoschistoceras* (Teichert, 1944, p. 87–89) as a result of further tripartition of the umbilical lobe of a 12-lobed *Metalegoceras*-type of suture. The resulting addition of a pair of third external lateral lobes and a pair of third dorsolateral lobes gives a suture composed of 16 primary lobes. The two species known to belong in *Pseudoschistoceras* are *P. simile* Teichert, from the Bulgadoo Shale of Western Australia, and *P. gigas* (Smith, 1927, p. 33–34), from the Bitauni beds of Timor. Smith referred his species to *Metalegoceras*, but the accompanying illustration shows that this form develops 16 lobes (Text-fig. 8E). Two pairs of the lobes could be considered incipient, so that the Timorian species is significantly less advanced than *Pseudoschistoceras simile* (Text-fig. 8F).

Spirolegoceras Miller, Furnish & Clark (1957) is a subdiscoidal genus with prominent longitudinal sculpture and sinuous constrictions. It forms a total of 12 lobes, which are developed to approximately the same degree as those of *Metalegoceras*, but is unlike most other metalegoceratids in the possession of prongs of the ventral lobe which are almost equal in width to the corresponding first lateral lobe. Additional studies of new collections are necessary before the relationship of *Spirolegoceras* to other metalegoceratids can be established. However, the type species, *Spirolegoceras fischeri*, should probably be considered as a form which has diverged slightly from the main evolutionary stem of the metalegoceratids.

Miller & Furnish (1957b, p. 65) included an additional genus, *Eothinites* Ruzhencev (1933), in the family Metalegoceratidae. Earlier, Ruzhencev (1956, p. 193–195) had placed *Eothinites* together with *Epiglyphioceras* in the new family Eothinitidae. He explained the undoubted similarity of sutural ontogeny in *Metalegoceras* and *Eothinites* as being due to parallel evolution. These two genera may be separated by the discoidal shell form of *Eothinites* and by the differences in outline of some sutural elements. However, the similarities between *Eothinites* and other metalegoceratids seem more significant than the differences; comparable variation in conch proportions is known in other ammonoid families and is

C. *M. striatum* Teichert. From the Lower Permian Nura Nura Member of the Poole Sandstone, Fitzroy Basin, Western Australia; internal suture based on Uni. W. A. holotype 20508, at a conch diameter of roughly 22 mm., external suture on Bur. Min. Res. C.P.C. hypotype 1769 at a slightly smaller diameter.

D. *M. clarkei* Miller. From the Lower Permian Nura Nura Member of the Poole Sandstone, Fitzroy Basin, Western Australia; based on Uni. W. A. syntype 19985, at a conch diameter of 25 mm.

E. *P. gigas* (Smith). From the Lower Permian (Baigendzhinian) Bitauni beds of Timor; based on Uni. W. A. hypotype 18105, at a conch diameter of 115 mm.

F. *P. simile* Teichert. From the Lower Permian Bulgadoo Shale, Carnarvon Basin, Western Australia; based on Uni. W. A. paratype 21440, at a conch diameter of approximately 80 mm.

displayed impressively within the genus *Metalegoceras*. Minor sutural variations must be associated inevitably with changes in whorl cross-section. Consequently, we are continuing to include *Eothinites* in the family Metalegoceratidae.

Genus JURESANITES Maximova, 1940

Type species.—*Juresanites primitivus* Maximova, 1940, p. 859.

Discussion.—The systematics and chronologic range of *Juresanites* have been discussed under the familial heading. Additional information on the genus is available in papers by Ruzhencev (1951, p. 117–119; 1952, p. 65–71). The sutural formula is:

$$(V_1V_1)L(U_2U_1U_2):ID$$

JURESANITES CAMPBELLI (Teichert & Glenister), 1952
Pl. 79, figs. 1-3; text-fig. 8A

Metalegoceras campbelli TEICHERT & GLENISTER, 1952, Jour. Paleontology, v. 26, p. 18–20, pl. 3, figs. 7–9, text-fig. 3E.

Description.—Little can be added to the existing description of this species. However, it is significant that even the largest known specimens of the species (phragmocone diameter of 12 mm.) have extremely shallow lobes on either side of the umbilical lobe. Only one pair of dorsolateral lobes is developed by the species, as the shallow lobe situated close to the umbilical seam is not known to cross over into the internal suture.

Comparisons.—Before making specific comparisons, the ontogenetic stage attained by the known specimens of *Juresanites campbelli* should be considered, as these forms are unusually small for metalegoceratids. Teichert & Glenister (1952, p. 14–15) discussed the possibility that *J. campbelli* is a dwarf development of *J. jacksoni*. They concluded that this relationship was improbable, in view of the normal marine aspect of the associated fauna. Their conclusion is supported by the fact that the abundant specimens of *J. campbelli* attain a fairly uniform size in two widely separated localities (Woolaga Creek and the vicinity of the Irwin Rriver) and in two stratigraphic horizons approximately 550 feet apart. In addition, a specimen from the Woolaga Creek area (Uni. W. A. hypotype 39070) shows crowding of the septa at a shell diameter of 6 mm., suggesting that this form is already mature at that diameter.

Juresanites campbelli is similar to immature representatives of *J. primitivus* in both sutural pattern and shell form. However, it differs from that Soviet species and from all other known representatives of the genus in the proportions of elements in the external suture. The first lateral saddle of *J. campbelli* is equal to, or greater in maximum width than, the corresponding ventral lobe. Most metalegoceratids develop a ventral lobe which is almost double the width of the first lateral saddle, and only in immature specimens of *J. primitivus* (Ruzhencev, 1952, text-fig. 19b) are these widths comparable. In addition, the saddles in *J. campbelli* are relatively low.

The stage of development of the lobes in the vicinity of the umbilicus of *J. campbelli* is approximately equal to that for *J. primitivus*, from the Asselian Stage of the Urals. However, the unusually small size of the Australian species makes detailed comparisons difficult and reduces its value as a biostratigraphic indicator. Consequently, the beds containing *J. campbelli* are taken, on purely stratigraphic grounds, to be slightly younger than those containing *J. jacksoni* and are referred to the Sakmarian and not to the Asselian Stage.

Occurrence.—All known representatives of *J. campbelli* are from the Irwin River district in the northern part of the Perth Basin of Western Australia. The holotype was collected from a thin limestone bed, close to the top of the Holmwood Shale, at a point situated 1200 yards on a bearing of 160° from the junction of the north and south branches of the Irwin River. This bed has yielded only the one ammonoid specimen, and rare indeterminate shell fragments constitute the only associated fauna. An additional specimen (Uni. W. A. 41404) is known from approximately the same horizon as the holotype. It came from the Holmwood Shale, about 125 feet below the base of the High Cliff Sandstone, 300 yards upstream from the Coal Seam Road crossing of Beckett's Gully. The paratypes are from a thin limestone bed which is 150 feet stratigraphically above the band of *Jure-*

sanites jacksoni and 1070 feet below the top of the Holmwood Shale. The bed is exposed in a heavily faulted area 200 yards west of the Nangetty-Holmwood boundary fence, 1 mile northwest of Prider's Lookout. At this locality *J. campbelli* is associated with *Uraloceras irwinense* and a numerically large and varied fauna of marine invertebrates (Teichert & Glenister, 1952, p. 14). Both these localities are in the valley of the Irwin River. In the southern or Woolaga Creek section of the Irwin River district, *J. campbelli* is known from a thin bed of limestone situated 184 feet below the contact of the Holmwood Shale and the High Cliff Sandstone (Playford, 1959, p. 14). This limestone can be traced for 2.5 miles along the strike. Uni. W. A. hypotype 39070 is from an exposure of the bed situated 3 miles 28 chains on a bearing of 139° from Mt. Budd. Numerous specimens of *J. campbelli* and *Uraloceras irwinense* are associated in the bed with an abundant fauna of brachiopods, gastropods, pelecypods, nautiloids, serpulids and conulariids. All occurrences of *J. campbelli* are referred to the Sakmarian Stage.

Repository.—Holotype 1981 is lodged in the Department of Geology of The University of Melbourne, and paratypes 32031–32035 and hypotype 39070 in the Department of Geology of The University of Western Australia.

JURESANITES JACKSONI (Etheridge), 1907
Pl. 81, figs. 1,2; text-fig. 8B

Gastrioceras jacksoni ETHERIDGE, 1907, Geol. Surv. W. Australia, Bull. 27, p. 36–37, pl. 9, figs. 1–3; DUN & DAVID, 1923, Royal Soc. New South Wales, Jour. Proc., v. 56, p. 249–252, pls. 11–13, text-figs. 1–4.
Paralegoceras jacksoni (Etheridge) THOMAS, 1929, Nature, v. 123, p. 946–948.
Metalegoceras jacksoni (Etheridge) MILLER, 1932, Am. Jour. Sci., ser. 5, v. 24, p. 433–442, 1 pl., text-figs. 2,3; TEICHERT, 1942, Jour. Paleontology, v. 16, p. 229–230, text-fig. 6B; TEICHERT & GLENISTER, 1952, Jour. Paleontology, v. 26, p. 16–18, pl. 3, figs. 1–6, pl. 4, fig. 1, text-figs. 3A–D.

Description.—*Juresanites jacksoni* has been adequately described from a large number of specimens, but it remains for certain details of the sutural pattern to be examined more precisely. Published accounts of the mature suture of this species show that a shallow lobe is centered on the umbilical seam. With the separation of primitive metalegoceratids into the genus *Juresanites*, it is of importance to determine whether this lobe lies in the internal or the external suture. A critical examination of the wealth of material now available shows that from its first appearance, this lobe lies just outside the umbilical seam. Figured specimen No. 37512, which formed the basis of Text-fig. 8B has this lobe in the external suture even at a shell diameter of 170 mm. The relatively shallow depth of the adventitious lobes which flank the primary umbilical lobe is of almost equal significance for the generic assignment of this species. Both the depth and the position of the lobes on the umbilicus indicate reference to *Juresanites* rather than *Metalegoceras*.

Comparisons.—*Juresanites kazakhorum* Ruzhencev (1952, p. 68–71, pl. 3, figs. 1–4, pl. 4, fig. 1, text-figs. 18b,20) from the early Sakmarian Stage in the Southern Urals of western Kazakhstan has a suture which is strikingly similar to that of *Juresanites jacksoni*, and the two species are probably of comparable age. However, *J. kazakhorum* has broader whorls, a more abrupt umbilical shoulder, and a wider umbilicus. The outer umbilical diameter of the Soviet species is some 60% of the shell diameter, whereas the corresponding proportion of *J. jacksoni* is typically about 45%. The other described species of *Juresanites*, *J. primitivus* Maximova (see Ruzhencev, 1952, p. 65–68, pl. 2, figs. 1–4, text-figs. 18a,19), and *J. campbelli* Teichert & Glenister have shallower lobes flanking the umbilical lobe.

Occurrence.—*Juresanites jacksoni* is abundant in a thin bed of the Beckett Member, 1220 feet below the top of the Holmwood Shale (total thickness 1800 feet). It occurs in an ammonoid coquina composed largely of the shells of this one species. Other fossils are virtually absent from the bed, and a few indeterminate specimens of nautiloids, gastropods, and pelecypods are the only other forms known. The similarity between the sutures of *J. jacksoni* and *J. kazakhorum* seems to indicate comparable ages for the containing beds, and the middle part of the Holmwood Shale is consequently correlated with the lower Sakmarian Stage [faunal assemblage 4 of the early Tastubian Kara-

murun "Series" in the Southern Urals (Ruzhencev, 1952, p. 39)l.

The Beckett Member of the Holmwood Shale crops out over a small area in the valley of the Irwin River, approximately 15 miles north of Mingenew, in the Perth Basin of Western Australia. The several parallel exposures of the *Juresanites* bed are assumed to have been produced by faulting of a single stratum.

One specimen of *J. jacksoni* (Uni. W. A. 41397) is known from the Woolaga Limestone Member of the Holmwood Shale. It was collected in the vicinity of Woolaga Creek, 184 feet below the base of the High Cliff Sandstone, in association with numerous specimens of *J. campbelli* and *Uraloceras irwinense*.

Repository.—Holotype 11980 and hypotypes 32030a–d, 35779 and 37512 are lodged with the Department of Geology, The University of Western Australia, and hypotype 13823 with the Peabody Museum of Natural History, Yale University.

Genus METALEGOCERAS Schindewolf, 1931

Type species.—*Paralegoceras sundaicum* form. *evoluta* Haniel, 1915, p. 60–64, pl. 48, figs. 4,6, text-figs. 16,17.

Discussion.—The systematics and chronologic range of *Metalegoceras* have been discussed under the familial heading. Additional information on the genus is available in papers by Ruzhencev (1951, p. 119–127; 1956, p. 129–146). Sutural formula for this genus is:

$$(V_1V_1)LU_2U_1:U_2ID$$

METALEGOCERAS STRIATUM Teichert, 1942
Pl. 79, figs. 8–11; text-fig. 8C

Metalegoceras striatum TEICHERT, 1942, Jour. Paleontology, v. 16, p. 230–231, pl. 35, fig. 1, text-fig. 6C.

Description.—Until recently, this species was known from only the holotype. This specimen is a poorly preserved limonitized portion of a phragmocone. The ultimate and penultimate whorls are incomplete, and the inner whorls have been destroyed during fossilization. Parts of the septa of an additional whorl are preserved on the outer surface of the specimen, and these leave a nearly perfect trace of the internal suture. Teichert (1942, p. 230) compared the preservation of the holotype to the "Skulpturesteinkern" type of fossilization of German paleontological literature (Quenstedt, 1928), and he considered the sutures on the outer surface of the holotype to be external sutures. However, the ventral convexity of the septal fragments at the base of the lobes leaves no doubt that these septa are remnants of an additional whorl. Teichert now considers that his illustration (1942, text-fig. 6c) is of the internal suture (written communication, April 10, 1957).

An additional incomplete phragmocone (Bur. Min. Res. C.P.C. hypotype 1769), from the same locality as the holotype of *M. striatum*, is probably conspecific with that specimen. This hypotype is distorted, but its shell proportions are about the same as those of the holotype, and the sutures of the two specimens probably are closely similar. However, only the broad outlines of the external suture can be obtained from the holotype, and only the gross configuration of the internal suture of the hypotype is discernible. Consequently, it is highly probable, but not certain, that the two specimens are conspecific.

Shell measurements and proportions for the holotype are given in Table 5. The whorls are evenly rounded across the venter and flanks, as far as the angular umbilical shoulder. The slightly convex umbilical walls are almost perpendicular to the plane of shell symmetry, and they bound a proportionally large umbilicus. Three deep constrictions are present in each whorl. They are directed forward across the umbilical wall, and extend to form a rounded salient across the venter. Fine growth lines parallel the course of the constrictions; the transverse elements are intersected by more prominent longitudinal lirations to give a reticulate sculpture. Where the shell has a diameter of about 12 mm., on the ventral side, there are approximately 10 transverse growth lamellae and 5 longitudinal lirations in 1 mm.

The external suture of the hypotype consists of a bifid ventral lobe with a relatively low secondary ventral saddle, a high rounded first lateral saddle, a broad lingulate first lateral lobe, a narrow asymmetric second lateral lobe, and a V-shaped umbilical lobe. The holotype shows the internal

suture to consist of a deep broad dorsal lobe, a shallower constricted first dorsolateral lobe, and an asymmetric second dorsolateral lobe.

Comparisons.—Information concerning the shell proportions of this species is inadequate, but the available figures suggest that the configuration of the conch is similar to that of *M. ajdaralense* (Ruzhencev, 1956, p. 138–140, pl. 10, figs. 3–5). All other Australian species of *Metalegoceras* and most of the Timorian representatives of the genus differ from *M. striatum* in developing moderately involute shells. The relatively great breadth of the first external lateral lobe of *M. striatum* may serve to distinguish this species, although details of sutural proportions are largely a function of ontogeny, and consequently, comparisons are difficult with the available Fitzroy Basin specimens. A marked asymmetry of the lobes which flank the umbilical lobe of the Australian species is closely similar to that of *M. sogurense* (Ruzhencev, 1956, p. 130–136) from the Southern Urals, and *M. schucherti* (Miller & Furnish, 1940, p. 99,100) from Texas.

Occurrence.—The two known representatives of this species are from near the top of the Nura Nura Member of the Poole Sandstone and were collected on Nura Nura Ridge in the Mt. Wynne area of the Fitzroy Basin, Western Australia. The exact parent locality of the holotype is unknown, but the hypotype came from 1.6 miles southeast of Paradise Homestead, at 18° 02 ½′ S., 124° 31′ E. *Metalegoceras striatum* is found associated with *M. clarkei*, *Thalassoceras wadei*, and *Propopanoceras ruzhencevi*, together with a small fauna of other mollusks, bryozoans, and brachiopods. The Nura Nura Member is correlated with the Callytharra Formation and the Fossil Cliff Formation (Teichert, 1941, p. 390). It is referred to the uppermost Sakmarian Stage.

Repository.—Holotype 20508 is lodged with the Department of Geology of The University of Western Australia, and hypotype 1769 with the Commonwealth of Australia Bureau of Mineral Resources, Canberra.

METALEGOCERAS CLARKEI Miller, 1936

Pl. 79, figs. 4–7; pl. 80, figs. 1–5; text-fig. 8D

Metalegoceras clarkei MILLER, 1936, Jour. Paleontology, v. 10, p. 687–688, pl. 92, figs. 1–7.
Metalegoceras tschernyschewi (Karpinsky) [part] RUZHENCEV, 1956, Acad. Sci. U.S.S.R., Paleont. Inst. Pub., v. 60, p. 143–146.

Description.—The discovery of additional representatives of this species confirms Miller's morphological observations. All 26 known specimens of the species are limonitized, and they are unsuitable for ontogenetic studies. Most are fragmentary internal molds of phragmocones. The largest com-

TABLE 5—DIMENSIONS (IN MM.) AND PROPORTIONS OF SPECIES OF *Metalegoceras*

	D	H	W	U	H/D	W/D	U/D
M. clarkei Miller							
Uni. W.A. 23241	28	13	—	6.5	.46	—	.23
syntype 19985	26.5	13	16	6.2	.49	.60	.23
Bur. Min. Res. F21624 A	24	10	14.5	6	.42	.60	.25
syntype 19986	13.9	6	9.2	4.5	.43	.66	.33
M. tscheryschewi (Karpinsky)							
hypotype 317/2679	102	39.6	66.7	31.0	.39	.65	.30
hypotype 317/2682	49.0	21.2	32.8	14.6	.43	.67	.30
hypotype 317/2685 Ruzhencev	30.4	12.5	18.7	10.1	.41	.61	.33
hypotype 317/2685 1956,	22.5	7.8	13.8	9.3	.35	.61	.41
hypotype 317/2685 p. 143	17.4	5.4	10.5	8.2	.31	.60	.48
M. striatum Teichert							
holotype 20508	16.5	5	10.5	7.5	.30	.64	.45
M. adjaralense Ruzhencev							
hypotype 317/3104 (Ruzhencev, 1956, p. 138)	16.8	5.7	11.6	7.3	.34	.69	.43

plete volution is septate and has a diameter of 26 mm.; fragments of larger whorls are present in the collection.

One specimen in the new collections (Uni. W. A. hypotype 35776) retains the ornament. Delicate growth lines are uniformly developed across the flanks and venter. They form a prominent rounded ventral sinus, a low rounded ventrolateral salient, and an extremely shallow sinus across the dorsolateral flanks. Fine longitudinal lirations are present in the vicinity of the umbilical shoulder, but they do not persist far onto the umbilical wall or onto the flanks.

Comparisons.—Miller (1936, p. 688) compared *Metalegoceras clarkei* with *M. tschernyschewi* (Karpinsky) from the Baigendzhinian Substage of the Southern Urals and possibly the Bitauni beds of Timor, and with *M. australe* (Smith) from the Bitauni beds of Timor. He concluded that these three species are closely comparable, but that *M. tschernyschewi* has a slightly larger umbilicus and *M. australe* a slightly smaller umbilicus than the Western Australian species. Ruzhencev (1956, p. 143–145) pointed out that the known specimens of *M. clarkei* are probably immature, and he placed this species in the synonymy of *M. tschernyschewi*.

The differences between the published sutures of *M. tschernyschewi* and *M. clarkei* are probably no more than can be expected from two different representations of the one species. However, Table 5 shows that the umbilicus of the Australian species is proportionally smaller than that of *M. tschernyschewi*. It should be noted that Miller (1936, p. 687) measured the umbilical diameter from the rounded umbilical shoulder. His measurements are consequently greater than those given in the present work, as umbilical measurements throughout the present paper are "inner" or minimum diameters. The available illustrations of *M. australe* (Smith, 1927, pl. 8, fig. 4) suggest that this species has an identical umbilical ratio to *M. clarkei* when specimens of similar size are compared. Miller (1936, p. 688) claimed that the umbilicus of *M. australe* is slightly smaller than that of *M. clarkei*, but it seems probable that he based the umbilical ratio of the Timor species on figures given by Smith (1927, p. 31), and these were for a much larger specimen than any known representative of *M. clarkei*. Most metalegoceratids became more involute as they increased in size, so that it is necessary to use only specimens of similar diameter before direct comparisons can be made. Smith figured two sutures of *M. australe*. However, the suture of the large holotype (1927, pl. 8, fig. 3) appears to be less advanced than that of the "youthful stage" (1927, pl. 8, fig. 6). This relationship illustrates the need for more nearly precise sutural diagrams of the Timor specimens, and the difficulty in making detailed comparisons with some of the existing figures.

Whether the Australian specimens are sufficiently distinct to have warranted the erection of a new species is open to question. However, the present authors are opposed to the suppression of *M. clarkei* until *M. australe* becomes better known. Published accounts suggest that *M. clarkei* is a valid species which differs from *M. tschernyschewi* in the possession of a smaller umbilicus and from *M. australe* in the details of the suture.

Metalegoceras hudsoni Miller & Furnish (1957a, p. 1049–1050, pl. 132, figs. 1–3, text-fig. 6B), from the Permian of Arabia, appears to have a suture which is practically identical to that of *M. clarkei*. The umbilical ratio of the Arabian species is slightly smaller than that of the Australian form.

Occurrence.—The 26 known representatives of this species are from near the top of the Nura Nura Member of the Poole Sandstone and were collected on Nura Nura Ridge in the Mt. Wynne area of the Fitzroy Basin of Western Australia. All specimens whose localities are known accurately are from 1.6 miles southwest of Paradise Homestead, at 18° 02 ½′ S., 124° 31′ E. *Metalegoceras clarkei* is found associated with *M. striatum*, *Thalassoceras wadei*, and *Propopanoceras ruzhencevi*, together with a small fauna of other mollusks, bryozoans, and brachiopods. The Nura Nura Member is correlated with the Callytharra Formation and the Fossil Cliff Formation (Teichert, 1941, p. 390). It is referred herein to the uppermost Sakmarian Stage.

Repository.—Cotypes 19985 and 19986 and hypotype 35776 are lodged with the Department of Geology of The University of Western Australia, and all other specimens (hypotypes 1767, 1768, specimens F.21624

A–J, F.21625 A–E) with the Commonwealth of Australia Bureau of Mineral Resources, Canberra.

METALEGOCERAS n. sp.
Pl. 83, fig. 9; text-fig. 9

cf. *Metalegoceras* CONDON, 1954, Australia Bur. Min. Res., Rept. 15, p. 52.
Metalegoceras cf. *M. clarkei* Miller THOMAS & DICKINS, 1954, Australian Jour. Sci., v. 16, p. 219.

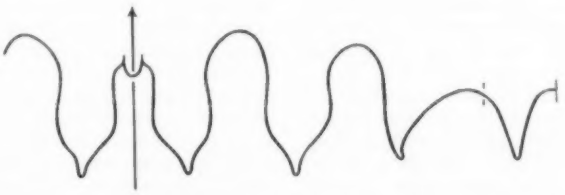
Description.—This species is known from a single fragmentary phragmocone with a maximum shell diameter of 125 mm. No portion of the shell is retained on the specimen, but a complete external suture is well exposed. The conch is moderately involute, and the umbilicus attains a diameter of only 22 mm. Weathering of one side of the shell makes it difficult to determine accurately the width of the conch. However, the greatest width lies close to the umbilical shoulder, and probably reaches a maximum of about 60 mm. The venter and the ventrolateral flanks are uniformly rounded, and the flanks are slightly flattened just ventrad of the rounded umbilical shoulder.

The external suture (Text-fig. 9) consists of a prominently bifid ventral lobe, two pairs of lateral lobes, and an umbilical lobe. The ventral lobe is subdivided by a high ventral saddle into two broad prongs, each of which is only slightly smaller (about 85%) than the corresponding first lateral lobe. The first lateral lobe is inflated medially; it is flanked by an unusually asymmetric hooked second lateral lobe, of slightly greater depth than the umbilical lobe. The umbilical lobe is narrowly V-shaped, and is roughly symmetrical. Details of the internal suture are not available.

Comparisons.—The curvature near the apex of the attenuated second lateral lobe and the relatively small umbilicus of *Metalegoceras* n. sp. enable this form to be differentiated from other Australian species of the genus. *Metalegoceras australe* (Smith, 1927, p. 31–32, pl. 8, figs. 1–6) from the Bitauni beds of Timor, and *M. tschernyschewi* (Karpinsky, 1889, p. 62, pl. 3, fig. 1) from the Baigendzhinian Substage of the Urals and possibly the Bitauni beds of Timor are similar to *M.* n. sp. in shell form, although both species have a slightly larger umbilical ratio. The three species also have approximately equal development of the second lateral lobe, but *M. tschernyschewi* differs from the other two species in having only a relatively low secondary ventral saddle. All other known species of *Metalegoceras* have a proportionally larger umbilicus.

An extreme representative of the family, *Spirolegoceras fischeri* Miller, Furnish & Clark (1957, p. 1064–1065, pl. 134, figs. 5–7, text-fig. 4) is similar to *Metalegoceras* n. sp. in many features, although the two forms are specifically distinct. The degree of development of the second lateral lobe of *M.* n. sp. is compatible with either a late Sakmarian or Artinskian age for the source beds.

Occurrence.—The single known specimen of *Metalegoceras* n. sp. was collected from near the base of the Callytharra Formation on Lyons River Station in the Carnarvon Basin of Western Australia. The locality is at a point (24° 31′ 23″ S., 115° 18′ 20″ E.) approximately 8 miles from Lyons River Homestead on a bearing of 344°, and 3.6 miles from Mead's Bore on a bearing of 112°. The associated fauna of the Callytharra Formation consists of over 100 species of



TEXT-FIG. 9—Diagrammatic representation of external suture of *Metalegoceras* n. sp. from the Lower Permian Callytharra Formation, Carnarvon Basin, Western Australia; based on Bur. Min. Res. C.P.C. figured specimen 1770, at a conch diameter of approximately 85 mm.

marine invertebrates (Teichert, 1952, p.121–122). The Callytharra Formation is correlated with the Fossil Cliff Formation and the Nura Nura Member of the Poole Sandstone (Teichert, 1941, p. 390), and is referred herein to the uppermost Sakmarian Stage.

Repository.—Figured specimen 1770 is lodged with the Commonwealth of Australia Bureau of Mineral Resources, Canberra.

Genus PSEUDOSCHISTOCERAS Teichert, 1944

Type species.—*Pseudoschistoceras simile* Teichert, 1944, p. 88–89, pl. 17, figs. 1–5, text-fig. 4.

Diagnosis.—Conch thickly discoidal and moderately evolute; free of conspicuous ornamentation, but may possess fine longitudinal lirae and transverse constrictions. Whorls relatively high and uniformly rounded across the venter and ventrolateral flanks. Mature suture consists of 16 lobes. Ventral lobe prominently subdivided by a moderately high secondary ventral saddle. Deep umbilical lobe flanked by shallow third dorsolateral lobe just inside the umbilical seam, and by shallow third lateral lobe just ventrad of the umbilical shoulder. All other lobes pointed and slightly constricted adorally. Phylogeny is assumed to include *Juresanites* and *Metalegoceras* as progenitors. The additional two pairs of lobes arise by a second tripartition of the umbilical lobe. The sutural formula is:

$$(V_1V_1)LU_2(U_{1\text{-}2}U_{1\text{-}1}{:}U_{1\text{-}2})U_2ID$$

Distribution.—Two species of *Pseudoschistoceras* are known. The type of the genus, *P. simile*, was described from the Bulgadoo Shale in the Carnarvon Basin of Western Australia. In addition, it is demonstrated herein that *Paralegoceras gigas* Smith (1927, p. 33–34), from the Bitauni beds of Timor, should also be referred to *Pseudoschistoceras*. Both species are of Baigendzhinian age.

Discussion.—The material on which the type species of *Pseudoschistoceras* is based is not suitable for ontogenetic studies. However, Teichert (1944, p. 88) believed the genus to have developed from the Pennsylvanian *Schistoceras*. He named the form accordingly, tentatively referred it to the Schistoceratidae, and considered it to be the terminal member of the *Pseudoparalegoceras*→*Diaboloceras*→*Paralegoceras*→*Schistoceras* lineage. Ruzhencev (1951, p. 116–117) considered that the similarities between *Schistoceras* and *Pseudoschistoceras* are superficial, and that *Pseudoschistoceras* should be included in the Metalegoceratidae as the end member of the *Juresanites*→*Metalegoceras* line. The present authors fully agree with this later suggestion. All stages in the phylogenetic sequence are known from Western Australia (Text-fig. 8).

The phylogeny of the schistoceratids differs fundamentally from that of the metalegoceratids. All schistoceratids exhibit a ventral migration of the primary umbilical lobe, during ontogeny, so that this lobe is situated on the flank in mature specimens. The more advanced representatives, *Pintoceras* and *Schistoceras*, developed a lobe on the umbilical wall, but all the lobes between the primary umbilical lobe and the first dorsolateral lobe are adventitious in origin (Miller & Furnish, 1958, text-fig. 4). Consequently the formula for *Schistoceras* is:

$$(V_1V_1)LU_1U_{2\text{-}2}U_{2\text{-}1}{:}U_{2\text{-}2}ID$$

The primary umbilical lobe remained on the umbilical wall during the phylogeny of the metalegoceratids. Additional lobes were added, during the ontogeny of representatives of the family, by the tripartition of the primary umbilical lobe. Consequently, although both the mature internal and external sutures of advanced metalegoceratids may be strikingly similar to those of advanced schistoceratids, the external sutures of the two families differ fundamentally in the ontogeny of their components.

All known species of *Schistoceras*, and particularly the more advanced members of that genus, exhibit exceptionally strong development of the prongs of the ventral lobe, so that these prongs are commonly similar in size and shape to the corresponding first lateral lobes. In addition, the secondary ventral saddle is high. One species, *Schistoceras suburalense* Ruzhencev (1950, p. 124–126), from the Upper Carboniferous of the Urals, has a secondary ventral saddle of almost equal height to the first lateral saddle, and prongs of the ventral lobe which are almost twice as wide as the corresponding first lateral lobes. *Schistoceras hyatti* Smith,

from the Virgilian of Texas, is known to have developed prongs of the ventral lobe which are twice the size of the first lateral lobe (Miller & Furnish, 1958, p. 264).

The prongs of the ventral lobe of both species of *Pseudoschistoceras* are similar to those of all other metalegoceratids, with the exception of *Spirolegoceras*, in that they are considerably smaller than the corresponding first lateral lobes (Text-fig. 8). Finally, the secondary ventral saddles of both species of *Pseudoschistoceras* are approximately two-thirds the height of the first lateral saddle, whereas species of *Schistoceras* have proportionally higher secondary ventral saddles. It is thus apparent that the ventral lobe of *Pseudoschistoceras* is strikingly similar to that of most other metalegoceratids and is less like that of *Schistoceras*.

Study of the late ontogenetic development of *P. gigas* (Text-fig. 8E) indicates that this form attained 16 lobes by tripartition of a 12-lobed suture similar to that of species of *Metalegoceras*. This tripartition is closely comparable with the sutural subdivision which produced the 12-lobed suture of *Juresanites* and *Metalegoceras*, and there is consequently little doubt that *Pseudoschistoceras* is the end member of the phylogenetic sequence from *Juresanites* through *Metalegoceras*.

PSEUDOSCHISTOCERAS SIMILE Teichert, 1944
Pl. 83, figs. 1–6; text-fig. 8F

Pseudoschistoceras simile TEICHERT, 1944, Jour. Paleontology, v. 18, p. 88–89, pl. 17, figs. 1–5, text-fig. 4.

Description.—Eight specimens of this species are available for examination. Seven of them are types used by Teichert, and the additional specimen is so poorly preserved that it is of little value. The shell is not retained on any of the available material, and the specimens are unsatisfactory for ontogenetic studies. However, the shell proportions and the mature suture are adequately shown. Shell dimensions and proportions are listed below. The largest known specimen (Uni. W. A. unfigured paratype 39097) is a portion of a phragmocone with a whorl height of approximately 50 mm. The complete phragmocone would have had a maximum over-all diameter of over 100 mm. Other specimens retain a maximum of one and one-quarter whorls of body chamber, so that the large paratype, when complete, would have attained an overall shell diameter of at least 200 mm.

The mature suture consists of 16 lobes (Text-fig. 8F). The ventral lobe is subdivided by a prominent secondary ventral saddle of about two-thirds the height of the first lateral saddle. Both the first and second lateral lobes are pointed, and are slightly constricted proximally. The prongs of the ventral lobe are equal in width to the second external lateral lobe and two-thirds the width of the first lateral lobe. A deep narrow umbilical lobe is flanked by a shallow third lateral lobe just ventrad of the umbilical shoulder, and by a comparable third dorsolateral lobe just inside the line of involution. The second dorsolateral lobe is deep, narrow, and markedly asymmetric. Both the dorsal and the first dorsolateral lobe are deep narrow and conspicuously constricted.

Comparisons.—*Pseudoschistoceras simile* is comparable with *P. gigas* (Smith, 1927, p. 33–34, pl. 5, figs. 1,2, pl. 6, figs. 1–7) from

TABLE 6—DIMENSIONS (IN MM.) AND PROPORTIONS OF TWO SPECIES OF *Pseudoschistoceras*

	D	H	W	U	H/D	W/D	U/D
P. simile Teichert							
holotype 21326	77	32	38	28	.42	.49	.36
paratype 21327	63	25	31	22	.40	.49	.35
paratype 21328	62	23	30	22	.37	.48	.35
paratype 21329	53	20	26	19	.38	.49	.36
P. gigas (Smith)							
hypotype 18105	177	64	75	63	.36	.42	.36
hypotype 18105	134	49	61	50	.37	.46	.37

the Baigendzhinian Substage at Bitauni and Noil Simaan, Timor, The two species are similar in shell proportions, but *P. simile* has an appreciably more advanced suture. The lobes which flank the umbilical lobe of *P. gigas* are extremely shallow (compare Text-figs. 8E and 8F).

Occurrence.—All known specimens of *P. simile* are from ¼ to ½ miles south of Barrabiddy Dam (23° 57′ S., 114° 31′ E.), on Wandagee Station, in the Carnarvon Basin of Western Australia. They were derived from the Barrabiddy Member of the Bulgadoo Shale (Teichert, 1952, p. 124), where they were associated with a prolific marine fauna. *Propinacoceras australe* is also known from the Bulgadoo Shale. The formation is referred to the Baigendzhinian Substage.

Repository.—Holotype 21326, figured paratypes 21327, 21329 and 21440, unfigured paratypes 21328, 39097 (renumbered from 21330a, as this number is preoccupied) and 39098 (renumbered from 21330b) are lodged with the Department of Geology, The University of Western Australia.

Family PARAGASTRIOCERATIDAE Ruzhencev, 1951

This family consists of a lirate group of gastrioceratids which ranges throughout almost the entire Permian System. It constitutes one of the dominant cephalopod elements in the Artinskian Stage of the Ural Mountains, where thousands of specimens have been collected, and occurs in the same relative abundance in the Guadalupian strata of Texas and Coahuila.

The following genera are now included in the family; *Paragastrioceras* Tchernow, 1907; *Uraloceras* Ruzhencev, 1936; *Synuraloceras* Ruzhencev, 1952; *Pseudogastrioceras* Spath, 1930; *Strigogoniatites* Spath, 1934; *Atsabites* Haniel, 1915; and *Epiglyphioceras* Spath, 1930.

Conch form within the family is extremely variable, and the suture likewise exhibits a considerable range in the proportions of the component elements. All members of the family have the same sutural formula:

$$(V_1V_1)LU{:}ID$$

In general, Lower Permian representatives are characterized by widely umbilicate conchs, finely lirate tests, and umbilical nodes. The most nearly consistent feature of these Lower Permian forms is a moderately pronounced ventral salient of the apertural margin. Upper Permian representatives are characteristically more nearly involute and are coarsely lirate; they also form a rounded hyponomic sinus.

It should be emphasized that morphologically intermediate forms link essentially all the proposed generic groups. Nevertheless, some definitions can be drawn which have stratigraphic significance.

Complete body chambers are rarely preserved in paragastrioceratids; however, Ruzhencev (*e.g.*, 1956, pl. 14, figs. 2a,b; pl. 24, figs. 3a,b) figured several Artinskian species of *Paragastrioceras* and *Uraloceras* which clearly possess apertural constrictions. Other modifications at full maturity include flattening of the flanks and venter, development of a ridge along the umbilical shoulder, and formation of a straightened ventral outline. The size attained by *Uraloceras* when growth ceased ranges from about 40 mm. to 150 mm. The Upper Permian representatives of the family known to us do not retain the fully mature apertural margin; fragmentary specimens indicate that a diameter of over 300 mm. was reached by some species.

Genus PARAGASTRIOCERAS Tchernow, 1907

Type species.—*Goniatites Jossae* de Verneuil, 1845, p. 371, pl. 26, fig. 2.

Diagnosis.—Typically widely umbilicate (ratio of umbilicus to conch diameter over 50%) with depressed trapezoidal whorls (ratio of whorl height to width approximately 40%) and heavy rounded umbilical nodes. Prongs of ventral lobe in suture typically conspicuously narrower than corresponding lateral lobes. Growth lines and transverse constrictions form high ventral salient.

All Paragastrioceratidae with depressed whorls and pronounced umbilical nodes are included in *Paragastrioceras*. Forms intermediate with *Uraloceras* have less well developed nodes, narrower conchs, and sutures in which the ventral prongs are approximately the same size as the lateral lobes.

Distribution.—Practically all the known representatives of *Paragastrioceras* are from the Ural Mountains. The genus appears first

in the middle of the Asselian Stage (faunal assemblage 2 of Ruzhencev, 1952, p. 38), and extends into the Baigendzhinian Substage of the Artinskian. Ruzhencev (1951, p. 142–150; 1952, p. 72–73; 1956, p. 153–178) has studied over 1500 specimens from the Urals, and recognizes 20 component species. Popow (1958, p. 148–149) has recently recorded *P.* cf. *verneuili* Ruzhencev from the Verkhoïan of the Kharaulakh Mountains and described the new species *P. subwandageense* from the Okhotsk-Kolymsk Watershed. Both these localities are in northeastern Siberia and the parent beds are of Artinskian age. *P. wandageense* Teichert from the Coolkilya Greywacke of Western Australia is the only undoubted species of the genus described from outside the Soviet Union, but the imperfectly known *P. admiralense* Plummer & Scott (1937, p. 223–224, pl. 22, fig. 1–9) from the Admiral Formation of Texas may also belong in the taxon.

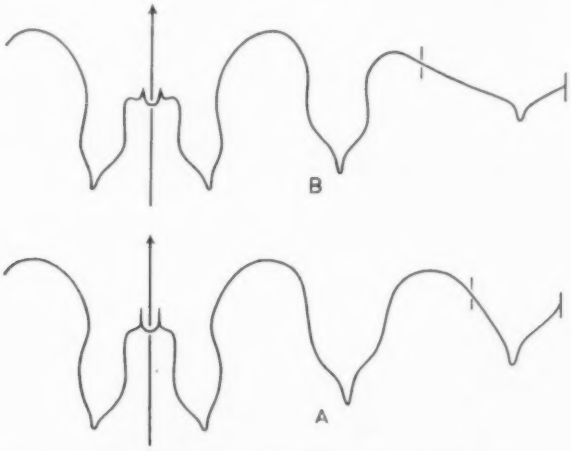
Discussion.—*Paragastrioceras* shows superficial resemblances to some Namurian gastrioceratids. *Gastrioceras*, in particular, possesses umbilical nodes and a similar shell form to *Paragastrioceras*, but may be distinguished generally by its lack of lirae and the presence of a hyponomic sinus. Lirate gastrioceratids are known in the Lower Pennsylvanian (*e.g.*, *Owenoceras* Miller & Furnish, 1940: type: *Neoglyphioceras bellilineatum* Miller & Owen, 1939, OD), but all differ significantly in a variety of other features.

The relationships of *Paragastrioceras* and *Uraloceras* are considered under the latter generic heading. Comparisons with Upper Permian forms are covered under *Pseudogastrioceras*.

PARAGASTRIOCERAS WANDAGEENSE
Teichert, 1942
Pl. 84, figs. 5–7; text-fig. 10A

Paragastrioceras wandageense TEICHERT, 1942, Jour. Paleontology, v. 16, p. 226–227, pl. 35, figs. 9,10.

Discussion.—No further representatives of this species have been discovered, and nothing can be added to Teichert's descrip-



TEXT-FIG. *10*—Diagrammatic representations of external sutures of *Paragastrioceras*.
A. *P. wandageense* Teichert. From the Lower Permian part of the Coolkilya Greywacke, Carnarvon Basin, Western Australia; based on Uni. W. A. holotype 20142, at a conch diameter of 19 mm. and a whorl width of 13 mm.
B. *P. jossae jossae* (de Verneuil). From the Lower Permian Baigendzhinian Substage of the Southern Urals; at a diameter of approximately 30 mm. and a whorl width of 17.7 mm. (from Ruzhencev, 1956, p. 172, fig. 56b).

tion of the holotype. A more nearly accurate sutural illustration is given in Text-figure 10A.

Comparisons.—Imperfect preservation and moderate size of the Australian specimens make detailed specific comparisons difficult. However, the conch form of *P. wandageense* lies within the known variation of the type species, *P. jossae*. The Australian holotype does not appear to develop the marked asymmetry of the second lateral saddle so characteristic of most species of *Paragastrioceras*, but this may be due, at least in part, to conch weathering.

Occurrence.—Teichert gave the locality of the holotype as "Two hundred yards north of Wandagee-Minilya Road, west side of syncline, north of Wandagee Hill. In lower part of *Linoproductus* stage of Wandagee series, at approximately the same horizon as *Helicoprion davisii*." In a later paper (1950, p. 1791) he formalized the nomenclature of the "*Linoproductus* stage" by naming it the "Coolkilya Sandstone." Condon (1954, p. 91–96) changed the name to Coolkilya Greywacke and revised the boundaries originally established by Teichert. The validity of these revisions was questioned (Teichert, 1957, p. 65–68) and the exact boundaries are still in doubt. However, the ammonoid horizons can be referred to the detailed section given by Teichert (1952, p. 117), and the reference below is to this section. The holotype of *Paragastrioceras wandageense* came from the lower beds of the Coolkilya Greywacke, probably from not more than 100 feet above the base of the formation (Teichert, 1952, p. 130), where it was associated with *Helicoprion davisii* (Woodward, see Teichert, 1940) and *Propinacoceras australe*. The containing beds are approximately 250 feet below the lowest occurrence of *Pseudogastrioceras goochi*, and the Lower-Upper Permian boundary is assumed to pass through the intervening interval. One additional specimen of *P. wandageense* was reported by Teichert to have been collected from the eastern side of the syncline north of Wandagee Hill, at the same horizon as the holotype. This specimen can no longer be found in the collection of The University of Western Australia.

Repository.—Holotype 20142 is lodged with the Department of Geology, The University of Western Australia.

Genus URALOCERAS Ruzhencev, 1936

Type species.—*Gastrioceras suessi* Karpinsky, 1889, p. 52, pl. 3, figs. 3a–g.

Diagnosis.—Shell subdiscoidal; typically widely umbilicate, but genus includes forms in which the umbilicus attains only one-fourth the conch diameter. Whorls approximately equidimensional but may be slightly compressed or depressed. Longitudinal lirae numerous and weakly developed in comparison with those of Upper Permian paragastrioceratids. Umbilical ribs present in early growth stages but may not persist onto mature whorls. Suture characterized by prongs of the ventral lobe which have the same dimensions as the lateral lobe or are slightly larger. Growth lines and transverse constrictions directed adorally to form ventral salient.

Distribution.—*Uraloceras* first appears in the Sakmarian Stage, and its range extends into the Baigendzhinian Substage of the

EXPLANATION OF PLATE 85

FIGS. *1,2,5–7*—*Pseudogastrioceras goochi* Teichert, from the Upper Permian of Western Australia. *1,2*, Uni. W. A. paratype 20505, ×1½, from the upper part of the Coolkilya Greywacke, Carnarvon Basin; *5,6* Bur. Min. Res. C.P.C. hypotype 1771, ×1½, from the Lightjack Member of the Liveringa Formation, Fitzroy Basin; *7*, Uni. W. A. hypotype 35777, ×1½, from an unknown horizon in the Coolkilya Greywacke, Carnarvon Basin (see also pl. 84, figs. 1–4).

3,4,8,9—*Uraloceras pokolbinense* (Teichert), from the Farley Formation, Sydney Basin, New South Wales. *3,4*, Uni. Sydney paratype 867, ×2; *8,9*, Uni. Sydney holotype 866, ×1.

1

3

5

2

8

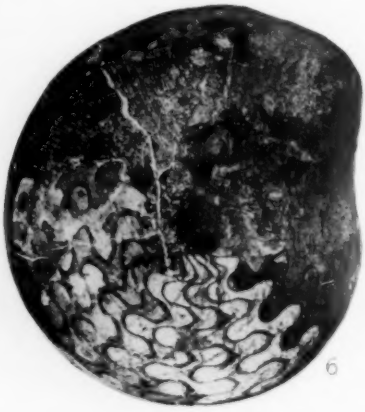
6

9

7

4

1


6

2

4

7

5

8

3

9

Artinskian Stage. Most of the known representatives are from the Ural Mountains, and 11 species have been described from this area (Ruzhencev, 1951, p. 150–155; 1956, p. 179–192). *U. irwinense* Teichert & Glenister, from the Holmwood Shale of Western Australia; and *U. pokolbinense* (Teichert), from the Farley Formation of New South Wales, are the only species described from beyond the Soviet Union. An additional undescribed species, probably referable to *Uraloceras*, is known from southeastern British Columbia.

Discussion.—In general, the form of the mature aperture distinguishes *Uraloceras* and other Lower Permian Paragastrioceratidae from the Upper Permian members of the family. *Synuraloceras* Ruzhencev, 1952 (type: *S. carinatum* Ruzhencev, 1952, OD) can be differentiated by its angular mature venter. Greater difficulty is encountered in distinguishing *Paragastrioceras*, for this genus is gradational with *Uraloceras*. The whorl cross-section in *Paragastrioceras* tends to be depressed, whereas the whorl height and width of *Uraloceras* are approximately equal. Both genera possess umbilical nodes or ribs in early growth stages; these structures persist or are accentuated in *Paragastrioceras* but are relatively inconspicuous in the mature whorls of *Uraloceras*. The proportionate size of the prongs in the ventral lobe of the suture may also serve to separate the two taxa. Mature *Uraloceras* develops prongs which equal or are appreciably larger than the adjacent lateral lobes, whereas the prongs in mature *Paragastrioceras* are equal to or smaller than the corresponding laterals.

URALOCERAS IRWINENSE Teichert & Glenister, 1952

Pl. 84, figs. 8–11; text-figs. 11A,12

Uraloceras irwinense TEICHERT & GLENISTER, 1952, Jour. Paleontology, v. 26, p. 21–22, pl. 4, figs. 2–7.

Discussion.—The discovery of five additional specimens of this species has yielded no further morphological information. In comparing this species with the numerous representatives from the Ural Mountains, it is important to remember that the largest known specimen of *U. irwinense*, the holotype, attains a maximum diameter of only 21 mm. However, the normal marine aspect of the associated fauna makes it improbable that the ammonoids are dwarf forms.

Comparisons.—*U. irwinense* is closely similar to species from both Sakmarian and Artinskian strata of the Ural Mountains. The conch proportions and suture of a Sakmarian species, *U. limatulum* Ruzhencev (1951, p. 154–155, pl. 13, figs. 5–7), are almost identical with those of *U. irwinense*, but the latter species can be differentiated by its relatively strong transverse ornamentation. *U. complanatum* (Voinova), from the Artinskian Stage (Ruzhencev, 1956, p. 182–184, pl. 25, figs. 2–6) is closely comparable with the Australian species, but differs in the possession of a more advanced external suture. The internal suture of *U. irwinense* is imperfectly known, but it appears to develop unusually long lobes. *U. pokolbinense* (Teichert), from the Lower Permian of eastern Australia has a much narrower umbilicus than the Western Australian species.

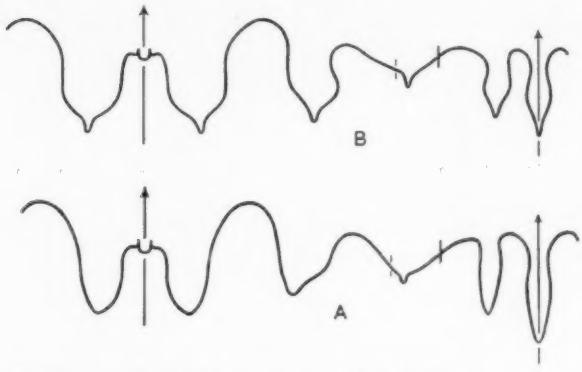
Occurrence.—All type specimens of *U. irwinense* are from a thin limestone bed which

EXPLANATION OF PLATE 86

FIGS. *1–3*—*Propopanoceras ruzhencevi* Glenister & Furnish, n. sp., from the Lower Permian Nura Nura Member of the Poole Sandstone, Fitzroy Basin, Western Australia, ×4. *1,2*, Bur. Min. Res. C.P.C. holotype 1773; *3*, Bur. Min. Res. C.P.C. paratype 1774.

4,5—*Neocrimites* sp. Bur. Min. Res. C.P.C. figured specimen 1776, ×3, from the Lower Permian Coyrie Formation, Carnarvon Basin, Western Australia (see also pl. 83, figs. 7,8).

6–9—*Neocrimites meridionalis* Teichert & Fletcher. Australian Mus. holotype F35732, ×2, from the Branxton Subgroup, Sydney Basin, New South Wales (figs. 6,7 are the same view of the holotype; fig. 6 was photographed under water, fig. 7 with a coating of ammonium chloride).



TEXT-FIG. *11*—Diagrammatic representations of sutures of *Uraloceras*.

A. *U. irwinense* Teichert & Glenister. From the Lower Permian Holmwood Shale, Perth Basin, Western Australia; based on Uni. W. A. paratypes 32037 (external suture) and 32038 (internal suture), at a conch diameter of approximately 9 mm. and a whorl height of approximately 3.5 mm.

B. *U. involutum* (Voinova). From the Lower Permian Aktastinian Substage of the Southern Urals; at a diameter of approximately 70 mm. and a whorl height of approximately 26 mm. (from Ruzhencev, 1956, p. 182, fig. 61d).

is 150 feet stratigraphically above the band of *Juresanites jacksoni* and 1070 feet below the top of the Holmwood Shale. The bed is exposed in a heavily faulted area 200 yards west of the Nangetty-Holmwood boundary fence and 1 mile northwest of Prider's Lookout, in the Irwin River district of the Perth Basin of Western Australia. At this locality *U. irwinense* is associated with *Juresanites campbelli* and a numerically large and varied fauna of marine invertebrates (Teichert & Glenister, 1952, p. 14). In the southern or Woolaga Creek section of the Irwin River district, *U. irwinense* is known from a thin bed of limestone situated in the Holmwood Shale 184 feet below the contact of this formation and the High Cliff Sandstone (Playford, 1959, p. 14–15). This limestone can be traced for 2.5 miles along the strike. Good exposures in the Woolaga Creek area occur at 3 miles 28 chains on a bearing of 139° from Mt. Budd, where numerous specimens of *U. irwinense* and *J. campbelli* are associated with an abundant fauna of brachiopods, gastropods, pelecypods, nautiloids, serpulids and conulariids. All occurrences of *U. irwinense* are referred to the Sakmarian.

TEXT-FIG. *12*—Diagrammatic representation of the cross-section of *Uraloceras irwinense* Teichert & Glenister, from the Lower Permian Holmwood Shale, Perth Basin, Western Australia; based on Uni. W. A. paratype 32039, ×4½, at a conch diameter of 15 mm.

Repository.—Holotype 32036 and paratypes 32037–32040 are lodged in the Department of Geology of The University of Western Australia.

URALOCERAS POKOLBINENSE
(Teichert), 1954
Pl. 85, figs. 3,4,8,9; text-fig. 13A

Pseudogastrioceras pokolbinense TEICHERT, 1954, Royal Soc. New South Wales, Jour. Proc., v. 87, p. 48–49, pl. 7, figs. 1–4, text-fig. 2.

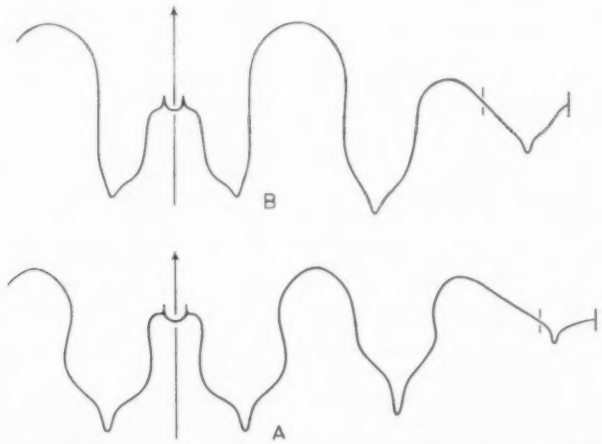
Discussion.—Little need be added to Teichert's original description of the two available representatives of this species, but the course of the constrictions warrants further comment. A broad shallow constriction traverses the body chamber of the holotype close to the fragmented adoral margin. It is almost directly transverse throughout, but is so shallow and broad across the venter that its course is difficult to determine in this area. A prominent constriction is present on the phragmocone of the paratype; it forms a sinus across the umbilical wall, a fold on the dorsolateral flanks close to the umbilical shoulder, a shallow rounded sinus across the flanks, a fold on the ventrolateral flanks, and a faint sinus across the venter.

Neither specimen is well enough preserved to exhibit the ornamentation satisfactorily. However, the internal mold of the holotype retains closely spaced longitudinal lirae which are too indistinct to be seen on the photograph.

Comparisons.—Although *Uraloceras pokolbinense* is not closely similar to *U. suessi*, it resembles several other species of this genus from the Artinskian of the Ural Mountains. The greatest apparent similarity is to *U. federowi* (Karpinsky). Topotypes of this species, which are available to us for study, agree almost precisely in conch proportions with the eastern Australian form. Fine shell ornament and sutures do not differ significantly. The one feature which distinguishes *U. pokolbinense* is the development of slightly biconvex growth lamellae, rather than the protractive aperture of all other representatives of the genus.

U. pokolbinense differs from known representatives of *Pseudogastrioceras* in the development of exceptionally wide prongs in the ventral lobe of the suture and in the possession of a delicately lirate test. Nevertheless, this species is somewhat transitional between the two genera in the form of the aperture.

Occurrence.—Both specimens are from Portion 74 of the Parish of Pokolbin, near



TEXT-FIG. *13*—Diagrammatic representations of external sutures of *Uraloceras* and *Pseudogastrioceras*.
A. *U. pokolbinense* (Teichert). From the Farley Formation of the Dalwood (Lower Marine) Group, Sydney Basin, New South Wales; based on Uni. Sydney holotype 866, at a conch diameter of 41 mm.
B. *P. altudense* (Böse). From the Upper Permian Word Formation, Texas; at a conch diameter of about 27 mm. (from Miller & Furnish, 1940, p. 86, fig. 22B).

the southern extremity of the Lochinvar Dome, in the Sydney Basin of New South Wales. This locality is about 3 miles southwest of Cessnock and 29 miles west of Newcastle. The types came from an unknown horizon thought to be within the Farley Formation of the Dalwood (Lower Marine) Group (Booker, 1955), and to be of either late Sakmarian or early Artinskian age.

Repository.—Holotype 866 and paratype 867 are lodged with the Department of Geology, The University of Sydney.

Genus PSEUDOGASTRIOCERAS Spath, 1930

Type species.—*Goniatites abichianus* Möller, 1879, p. 225–243 (as figured by Abich, 1878, pl. 1, figs. 1–3, pl. 11, fig. 2).

Diagnosis.—Conch typically subdiscoidal and narrowly umbilicate, but genus includes thickly subdiscoidal forms as well as those with wide umbilici. Test strongly lirate; growth lamellae and constrictions biconvex and form prominent rounded hyponomic sinuses. Shell sculpture tends to be localized on ventral part of shell and constrictions to be lacking in late growth stages. Exact sutural proportions vary, in part with shape of whorl, but ventral prongs and lateral lobes are subequal.

Distribution.—*Pseudogastrioceras* is characteristic of Upper Permian strata in various parts of the world. It constitutes one of the common elements in the Guadalupian of Texas and Coahuila. The genus occurs abundantly, however, in the Phosphoria and Park City formations of the Rocky Mountains; in some localities as a shell aggregate, almost to the total exclusion of other fossils. The cephalopod faunas of both these formations are considered (Miller, Furnish & Clark, 1957, p. 1057) to be of Leonardian age (upper Artinskian Stage). Strata of similar age have yielded *Pseudogastrioceras* in the Colorado Plateau (Miller & Furnish, 1958, p. 682–683), the Midcontinent Region (Clifton, 1942, p. 697–698), British Columbia (near Kamloops) and the Canadian Arctic Archipelago (Harker & Thorsteinsson, 1960, p. 74–77).

Other recorded occurrences of *Pseudogastrioceras* are almost entirely of Upper Permian age. The genus has been described from numerous horizons and localities in the Guadalupian strata of West Texas and Coahuila (Miller & Furnish, 1940, p. 82–93; Miller, 1944, p. 88–92). Gemmellaro (1887, p. 87–89; 1888, p. 31) distinguished three species from the classic Sosio Limestone of Sicily. The imperfectly known *Paralegoceras* sp. (Cowper Reed, 1936, p. 367–368, pl. 65, figs. 5,5a), from the Middle *Productus* Limestone of northern Pakistan, is almost certainly a paragastrioceratid and may belong in *Pseudogastrioceras*. Australian representatives are included in *P. goochi* Teichert, and are known from the Coolkilya Greywacke and the Liveringa Formation of Western Australia. The type of the genus, *P. abichianum* (Möller), occurs in the Dzhulfian strata of Armenia, which are regarded as uppermost Permian and possibly also earliest Triassic in age.

Discussion.—The exact relationship of typical *Pseudogastrioceras* to the majority of Upper Permian representatives of the genus is somewhat uncertain. The type, *P. abichianum*, occurs in the uppermost Permian in association with otoceratids of early Triassic affinities (Stoyanow, 1909, p. 103–105) and the exact form of the aperture of this species can only be inferred. Virtually all other representatives of the genus have been found in strata of Guadalupian age; these forms possess a prominent hyponomic sinus and have been distinguished, primarily on this basis, as a separate taxon, *Altudoceras* Ruzhencev, 1940 (type: *Gastrioceras altudense* Böse, 1919, OD). Despite the fact that *P. abichianum* is described from internal molds, the shell almost certainly formed an apertural margin similar to that of *G. altudense*. Many Guadalupian paragastrioceratids which possess the characteristic ribs and constrictions in early evolute whorls may lack these features in later growth stages. The involute conch of *P. abichianum* represents an extreme in the phylogenetic trend but is not significantly different in this respect from even lower Guadalupian species such as *P. roadense* (*e.g.*, Miller & Furnish, 1940, pls. 16,17).

Some Lower Permian representatives of *Pseudogastrioceras* can be distinguished from Upper Permian species by the sutural proportions. For example, *P. simulator* (Girty) from the Phosphoria Formation of the Rocky Mountains is characterized by a

relatively narrow ventral lobe. This generalization does not serve in all cases.

Synuraloceras Ruzhencev, 1952 (type: *S. carinatum* Ruzhencev, 1952, OD) was erected for a rare species from the early Sakmarian Stage of the Southern Urals. It differs from other Lower Permian paragastrioceratids in the absence of conspicuous ornamentation and in the development of an angular venter, but resembles most Lower Permian representatives of the family in the possession of a high ventral salient across the apertural margin. The external sutures of *S. carinatum* resemble those of the various species of *Strigogoniatites*, but these similarities may stem from the closely comparable whorl sections of the two genera. Ruzhencev (1952, p. 73–74) claimed that *Strigogoniatites* evolved directly from *Synuraloceras*. However, in view of the extreme variability of the paragastrioceratid whorl cross-section, it is probable that the angular venter was developed independently by two separate groups. The evidence still suggests that *Strigogoniatites* was derived from *Pseudogastrioceras*, whereas *Synuraloceras* arose from one of the early Permian forms, possibly a weakly ornamented discoidal *Paragastrioceras*. Derivation from *Uraloceras* is also possible, but species of this genus possess larger prongs of the ventral lobe.

Strigogoniatites Spath, 1934 (type: *Glyphioceras angulatum* Haniel, 1915, OD) resembles *Pseudogastrioceras* and is gradational with it, but may be distinguished by the development of an angular venter in late growth stages. American representatives of *Strigogoniatites* are restricted to upper Guadalupian strata (Miller & Furnish, 1940, p. 94–95), but the exact age of the Timorian type species is unknown (Haniel, 1915, p. 51–54). *Gastrioceras zitteli* Gemmellaro (1887, pl. 6, fig. 20), from the Sosio Limestone of Sicily has a narrowly rounded venter and can be regarded as a primitive representative of *Strigogoniatites*. Two species described from the "Kufeng" Formation of Kwangsi (Chao, 1955, p. 143–145, 154–156, pl. 2, figs. 7–12) are probably derived from uppermost Permian strata. *Grabauites* Sun, 1947 [type: *Gastrioceras* (*Girtyites*) *liui* Grabau, 1924, OD] from the "Lopingian" Hoshan Formation of the same general area is imperfectly known, but the distinctive ornament suggests that it is a crushed *Strigogoniatites*.

Epiglyphioceras Spath, 1930 (type: *Glyphioceras Meneghinii* Gemmellaro, 1887, OD), from the Sosio Limestone of Sicily, is superficially unlike other Upper Permian gastrioceratids. However, we regard this genus as merely an evolute extreme, for otherwise it possesses the basic features of the group. Ruzhencev (1956, p. 193–195) linked *Epiglyphioceras* with a Lower Permian genus in proposing the Eothinitidae (type: *Eothinites* Ruzhencev, 1933). Evidence presented herein under the familial heading Metalegoceratidae indicates that *Eothinites* is an extreme variant of that family; *Epiglyphioceras* is an analogous member of the Paragastrioceratidae. Ontogeny of the suture as well as stratigraphic occurrence establish that there is no close relationship between *Epiglyphioceras* and *Eothinites;* they can be considered as homeomorphic only in gross form.

Atsabites Haniel, 1915 (type: *A. Weberi* Haniel, 1915, OD), from the Artinskian of Hatu Dame in Timor, is another evolute Permian gastrioceratid. Ruzhencev (1957, p. 59) regarded this genus as belonging in the Eupleuroceratidae (type: *Eupleuroceras* Miller & Cline, 1934); the single known species of *Eupleuroceras* is a keeled form from the Missourian Stage of the Midcontinent. *Atsabites* and *Eupleuroceras* may be regarded as aberrant representatives of families which are characteristically subdiscoidal, but the genera are quite unrelated. An additional taxon *Anatsabites* Ruzhencev, 1957 (type: *Paraceltites multiliratus* Plummer & Scott, 1937, OD) from the Upper Permian Word Formation of Texas may not be sufficiently distinct from *Atsabites* to warrant recognition.

PSEUDOGASTRIOCERAS GOOCHI Teichert, 1942

Pl. 84, figs. 1–4; pl. 85, fig. 1,2,5–7, text-figs. 14A–C

Pseudogastrioceras goochi TEICHERT, 1942, Jour. Paleontology, v. 16, p. 227–229, pl. 35, figs. 12–16, text-fig. 5B.

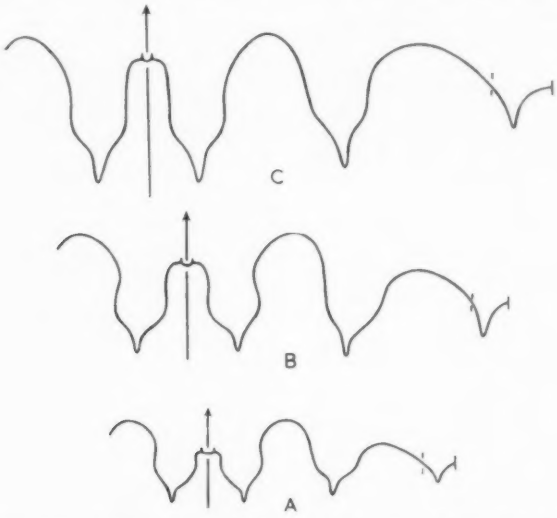
Pseudogastrioceras sp. TEICHERT, *ibid.*, p. 229, pl. 35, fig. 8.

Description of type material.—Teichert referred three specimens to this species. All

three were from the Coolkilya Greywacke of the Carnarvon Basin. Published descriptions of these forms are adequate, and a sutural drawing of the holotype is included in the accompanying Text-figure 14C.

Additional material.—One additional specimen of this species (Uni. W.A. hypotype 35777) has been collected from the Coolkilya Greywacke. It retains the prominent longitudinal lirae but does not show a suture satisfactorily.

Two further specimens (Bur. Min. Res. C.P.C. hypotypes 1771, 1772) were discovered in the Lightjack Member of the Liveringa Formation at Duchess Ridge in the Fitzroy Basin. One specimen (hypotype 1771) is of similar size to paratype 20505 from the Carnarvon Basin. Its suture is well exposed, and it agrees in all particulars with the paratype. The remaining specimen (hypotype 1772) is a well-preserved ferruginized phragmocone which attains a maximum shell diameter of only 12 mm. Table 7 shows that the whorls of this specimen are more depressed than those of larger representatives of *P. goochi*. However, most paragastrioceratids have whorls which are conspicuously more depressed at smaller diameters than in larger parts of the conch. Prominent ribs are present across the umbilical shoulder and the adjacent parts of the umbilical wall and flanks of the small hypotype. Nine occur in the ultimate half-whorl. The depressions preceding each fourth node continue to the venter as a constriction. These constrictions form a salient on the ventrolateral flanks, and a broad rounded sinus across the venter. Similar nodes and constrictions commonly occur in immature paragastrioceratids, but they may not persist into the outer whorls of larger shells. The sutures are represented by the accompanying Text-figure 14A. They are similar to those of the larger specimens of



TEXT-FIG. *14*—Diagrammatic representations of external sutures of *Pseudogastrioceras goochi* Teichert.

A. From the Upper Permian Lightjack Member of the Liveringa Formation, Fitzroy Basin, Western Australia; based on Bur. Min. Res. C.P.C. hypotype 1772, at a conch diameter of 12 mm.

B. From the Upper Permian Lightjack Member of the Liveringa Formation, Fitzroy Basin, Western Australia; based on Bur. Min. Res. C.P.C. hypotype 1771, at a conch diameter of 41 mm.

C. From the Upper Permian part of the Coolkilya Greywacke, Carnarvon Basin, Western Australia; based on Uni. W. A. holotype 20504, at a conch diameter of 90 mm.

TABLE 7—DIMENSIONS (IN MM.) AND PROPORTIONS OF AUSTRALIAN SPECIES OF *Uraloceras* AND *Pseudogastrioceras*

	D	H	W	U	H/D	W/D	U/D
U. pokolbinense (Teichert)							
holotype 866	57	26	24	14	.46	.42	.25
paratype 867	25.5	11	12	6	.43	.47	.24
P. goochi Teichert							
holotype 20504	98	45	40	31	.46	.41	.32
hypotype 35777	58	28	28	?	.48	.48	—
hypotype 1771	47	23	?24	8.5	.49	.51	.18
paratype 20505	45	22	23	8.5	.49	.51	.19
hypotype 1772	12	6	7.6	3	.50	.63	.25

P. goochi, but the lobes are proportionally shallower. Similar differences are generally encountered in the ontogeny of paragastrioceratids. Both the morphology of this specimen and its close association with an undoubted representative of *P. goochi* thus suggest that it is an immature form belonging to this species.

An additional small specimen from approximately the same locality and horizon as the type material of *P. goochi* (Uni. W.A. specimen 20507) was referred by Teichert (1942, p. 299, pl. 35, fig. 8) to "*Pseudogastrioceras* sp." This specimen is a poorly preserved fragment of a single whorl, in which septa are not discernible. Its diameter is difficult to estimate, but would have been of the order of 15–20 mm. Teichert believed that "The depressed whorl section and the presence of constrictions of the conch will serve to distinguish this species from *Pseudogastrioceras goochi*." However, the general physiognomy of this specimen is closely comparable with that of the slightly smaller hypotype (1772) from Duchess Ridge. The constrictions, umbilical nodes, and depressed whorl cross-section should be expected in a small representative of *P. goochi*, and the specimen is most reasonably referred to this species.

Comparisons.—Teichert compared *Pseudogastrioceras goochi* with *Uraloceras suessi* (Karpinsky, 1889) and *Paragastrioceras karpinskii* (Frédérix, 1915) from the Artinskian of the Ural Mountains, but the similarities with these species are considered to be superficial. Teichert also drew attention to the similarities between the species under discussion and *P. roadense* (Böse) from the Guadalupian beds of Texas and Mexico. The conch proportions and ornamentation of the two species are almost identical and only details of the suture, such as the high secondary ventral saddle in *P. goochi*, permit their separation. Undoubtedly, the closest affinities of the Australian species are with *P. roadense*. Ruzhencev (1951, p. 150) doubtfully referred the Australian species to *Uraloceras*, but he was unaware of the ventral sinus in the constrictions. The unusually wide external lobes of *U. pokolbinense* serve to distinguish it from *P. goochi*.

Occurrence.—All the known occurrences are from either the Coolkilya Greywacke in the Carnarvon Basin or the Lightjack Member of the Liveringa Formation in the Fitzroy Basin of Western Australia. Teichert (1942, p. 228) reported that the holotype of *P. goochi* came from "Somewhat above the basal beds (approximately *Thamnopora-Cleiothyridina* zone) of the *Linoproductus* stage of the Wandagee series, near mouth of northeastern gully of Wandagee Hill, on fence dividing Shed and Mungadan Paddocks, Wandagee Station." The "*Linoproductus* stage" is now known as the Coolkilya Greywacke (see herein under "Occurrence" heading of *Paragastrioceras wandageense*), and the holotype probably came from approximately 350 feet above the base of this formation (Coolkilya Greywacke used in the sense of Teichert, 1952, p. 117). This is assumed to be the lowest known occurrence of *P. goochi* and is at least 250 feet above the horizon of *Paragastrioceras wandageense*. The Lower-Upper Permian boundary is placed within this 250-foot interval. Other specimens of *P. goochi* were reported by Teichert (1942, p. 228–229) from the same general area as the

holotype. Some of them were from the same horizon as the holotype, but others came from higher horizons. The uppermost known occurrence is from approximately 90 feet below the top of the Coolkilya Greywacke, where it was found in association with *Agathiceras applanatum* (Teichert, 1952, p. 130).

The additional specimen from the Carnarvon Basin (Uni. W.A. hypotype 35777) was collected on Wandagee Hill in rubble from the Coolkilya Greywacke. Both specimens from the Fitzroy Basin (Bur. Min. Res. C.P.C. hypotypes 1771 and 1772) are from Duchess Ridge about 2 miles south of Mt. Nichol, at 18°, 08′ 40″ S., 124° 30′ 25″ E., in the Lightjack Member of the Liveringa Formation. Hypotype 1771 came from 52 feet above the base of the formation and hypotype 1772 from about 57 feet above the base. All the beds known to contain *P. goochi* are referred to the early Guadalupian Stage of the Upper Permian.

Repository.—Holotype 20504, paratypes 20505 and 20506, and hypotypes 20507 and 35777 are lodged with the Department of Geology, The University of Western Australia, and hypotypes 1771 and 1772 with the Commonwealth of Australia Bureau of Mineral Resources, Canberra.

Family Popanoceratidae Hyatt, 1900

A detailed treatment of the Popanoceratidae is included in a monographic study of the Lower Permian ammonoids from the Southern Urals (Ruzhencev, 1951, p. 160–174). An additional brief analysis of the family is given by Miller & Furnish (1957b, p. 52–53).

A discoidal conch, series of broad complexly subdivided lateral lobes, and prominent transverse ornament are characteristic. The somewhat similar marathonitids have a subglobular form and develop lobes which are more or less uniformly trifid. A related taxon, represented by *Hyattoceras*, is distinguished primarily by phylloid sutures.

Ruzhencev (1956, p. 223, 231) has illustrated the ontogenetic development of the sutures in typical representatives of the family. The inner evolute whorls present a general similarity in this respect to other Cyclolobaceae and to the Agathiceratacea. Fully mature conchs commonly reach a diameter of some 50 mm. Apertural modifications at maturity include prominent lateral constrictions, flattened venter, and accentuated hyponomic sinus. The body chamber is about a volution in length.

The Popanoceratidae represents a distinctive morphological group in which a single phylogenetic sequence is discernible. A primitive representative occurs in the late Asselian Stage of the Southern Urals. The family is common and widely distributed in the Lower Permian and in lower Guadalupian strata. The immature holotype of *Parapopanoceras dyadicum* Haniel (1915, p. 106–108, pl. 52, figs. 6 a–c), from the late Permian of Timor, is not closely related.

Two reasonably distinct genera can be recognized: *Popanoceras* Hyatt, 1884, and *Propopanoceras* Toumansky, 1938. Other generic proposals are regarded as synonyms (Miller & Furnish, 1957b, p. 52–53).

Genus Propopanoceras Toumansky, 1938

Type species: *Popanoceras lahuseni* Karpinsky, 1889, p. 67, pl. 5, figs. 1–3.

Diagnosis.—Conch thinly discoidal (W/D order of 35%) and with narrow umbilicus (some 10%–15% at maturity). Characteristically prominent sinuous ribs are weakly biconvex and slightly oblique, posteriorly; they also form conspicuous rounded ventral sinus. Constrictions generally numerous and parallel to ribs; typically deeply depressed on flanks and shallow across venter. Primary lateral lobe is divided during ontogenetic development into four or five independent lobes. Fourth or fifth lobe may become so deeply dissected in mature sutures that subdivisions could be considered additional independent lobes. Prongs of ventral lobe prominently bifid and narrower than first lateral lobe. First and second lateral lobes bifid to quadrifid, third lateral simple to trifid, fourth simple to deeply trifid, fifth entire or bifid. Primary umbilical lobe generally situated close to umbilical shoulder; several shallow incipient lobes may form between it and umbilical seam, and a characteristically V-shaped adventitious lobe separates it from lateral lobes. Dorsal lobe narrowly trifid; dorsolateral elements similar in number to those of external suture. First and second dorsolateral lobes separate

and bifid. Basic sutural formula is:

$$(V_1V_1)L_2L_1L_{2\text{-}1}(L_{2\text{-}1\text{-}1}L_{2\text{-}1\text{-}1})U^2U_1{:}U^1U_2(I_{2\text{-}1\text{-}1}I_{2\text{-}1\text{-}1})\cdot I_{2\text{-}1}I_{1\text{-}1}I_{1\text{-}2}D$$

but slightly simpler and somewhat more complex forms are also included.

Distribution.—Soviet representatives of *Propopanoceras* first make their appearance in the Kurmaya "Series" of the late Asselian Stage and extend through the Sterlitamakian "Horizon." The genus is common in the Southern Urals; it is noteworthy that all but five of the known representatives are from the Sakmarian Stage in this area. In addition to the type, Ruzhencev has described and named three Sakmarian species: *Propopanoceras simense* (1951, p. 167–169, pl. 14, figs. 5–8). *P. postsimense* (1951, p. 169–170, pl. 14, figs. 9,10), and *P. incallidum* (1938, p. 261, pl. 4, figs. 9,10). *Popanoceras sublahuseni* Gerassimov (1937, p. 18, pl. 2, figs. 2a,b) from the late Asselian Stage of the Southern Urals is also referable to this genus. The Australian *P. ruzhencevi* Glenister & Furnish, n. sp., is from beds assumed to be late Sakmarian in age. An additional undescribed species occurs in the Wolfcamp Formation of the Glass Mountains. *Popanoceras boesei* Smith from the Somohole beds of Timor (1927, p. 51–52, pl. 15, figs. 1,2) may represent this genus, but the suture is unknown.

Discussion.—Typical *Popanoceras* is distinguished from *Propopanoceras* by the development of wider prongs of the ventral lobe. Mature representatives of the more primitive *Propopanoceras* have bifid prongs of the ventral lobe which are appreciably narrower than the adjacent first lateral lobe; whereas the more complexly subdivided prongs of mature *Popanoceras* are as wide or wider than the corresponding first lateral. Typically there is one less subdivision of the primary first lateral lobe in *Propopanoceras* than in *Popanoceras*. Another difference can be noted in the paired first and second dorsolateral lobes of *Popanoceras*. Transverse constrictions in the early growth stages of *Propopanoceras* tend to be restricted and deeply impressed on the flanks. Further localization is apparent on immature *Popanoceras* in which the constrictions have become reduced to a series of distinctive circular pits, as many as thirteen per volution. The basic sutural formula for *Popanoceras* is:

$$(V_1V_1)L_2L_1L_{2\text{-}1}(L_{2\text{-}1\text{-}1}L_{2\text{-}1\text{-}1})U^1U_1{:}U^2U_2(I_{2\text{-}1\text{-}1}I_{2\text{-}1\text{-}1})I_{2\text{-}1}(I_{1\text{-}1}I_{1\text{-}2})D$$

Popanoceras annae Ruzhencev (1940, p. 78–80, pl. 2, fig. f, pl. 3, fig. 9, pl. 5, figs. 7–10) is morphologically intermediate between *Popanoceras* and *Propopanoceras*. Prongs of the ventral lobe are relatively narrow and, in some cases, bifid. Also, the paired nature of the dorsolateral lobes is less pronounced. The evidence from this and other species indicates that the two genera are gradational, although the known stratigraphic ranges do not overlap the Sakmarian-Artinskian boundary.

Popanoceras sublahuseni Gerassimov, the oldest and most primitive member of the family, is known from only two specimens. This species is the only known representative of *Protopopanoceras* Ruzhencev (1938, p. 260). Dissection of the lateral lobes is less than in typical *Propopanoceras*, but this character alone does not appear to be sufficiently marked to serve as a basis for generic differentiation.

Tauroceras Toumansky (1938a, p. 145–146), with type species *Popanoceras scrobiculatum* Gemmellaro (1888, p. 23–24, pl. 3, figs. 22–26, pl. 8, fig. 26) from the Sosio beds of Sicily, was proposed for advanced popanoceratids with highly dissected lateral lobes. No morphologic detail appears stable enough to permit confident separation of the advanced species into a distinct taxon. The name should be suppressed, therefore, as a synonym of *Popanoceras*.

PROPOPANOCERAS RUZHENCEVI
Glenister & Furnish, n. sp.
Pl. 86, figs. 1–3; text-fig. 15A

cf. *Popanoceras indo-australicum* Haniel THOMAS & DICKINS, 1954, p. 221.

Description.—Two specimens of this species are known to the authors. The holotype is a well preserved internal mold of a phragmocone with a maximum shell diameter of 13.1 mm., and the paratype is a crushed internal mold of a fragment from a phragmocone of slightly greater diameter. Both specimens are limonitized and are unsuitable for ontogenetic studies. The conch is thinly discoidal, and develops flattened

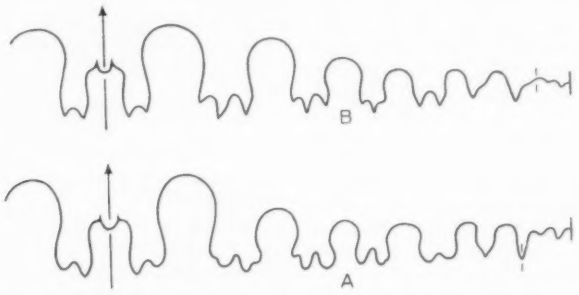
TABLE 8—DIMENSIONS (IN MM.) AND PROPORTIONS OF TWO SPECIES OF *Propopanoceras*

	D	H	W	U	H/D	W/D	U/D
P. ruzhencevi Glenister & Furnish (holotype)	13.1	6.3	5.1	2.2	.48	.39	.17
P. simense Ruzhencev (1951, p. 168)	12.7	6.1	5.0	1.9	.48	.39	.15

lateral flanks and uniformly rounded ventrolateral flanks and venter. The umbilicus is narrow and is bounded by gently curved umbilical walls and rounded umbilical shoulders. Shell measurements and proportions are given in Table 8. Five constrictions are present in the ultimate whorl of the holotype, but ribs are not reflected on the internal mold. The constrictions form a low fold across the dorsolateral flanks and are impressed strongly across the central part of the flanks, where they form a broad shallow sinus. A relatively narrow low salient is present across the ventrolateral flanks, and a deep but narrow sinus is weakly impressed across the venter.

The external suture, represented by Text-fig. 15A, was drawn mainly from the holotype, but the lobes across the dorsolateral flanks are preserved better on the paratype and were drawn from that specimen. All the secondary subdivisions of the lobes (Text-fig. 15A) are gently rounded, as they appear rounded in the imperfectly preserved holotype. However, several of them are elongate and pointed in the paratype, and there is no doubt that better preserved specimens will eventually demonstrate that all these secondary subdivisions are angular in mature specimens.

Comparisons.—The two available specimens of *Propopanoceras ruzhencevi* differ slightly in the proportions of the lateral lobes. This variation, plus the small diameter of the specimens, makes detailed specific comparison difficult. In addition, the shell is not preserved on the Australian material. However, the lobes of *P. ruzhencevi* are more strongly divided than in other named representatives of the genus at comparable ontogenetic stages. The closest sutural similarities are with the imperfectly known *Propopanoceras* sp. nov. (Ruzhencev, 1951, p. 173–174) from the Sterlitamakian of the Urals. These facts indicate that the Australian species lies close to the



TEXT-FIG. 15—Diagrammatic representations of external sutures of *Propopanoceras*.
A. *P. ruzhencevi* Glenister & Furnish, n. sp. From the Lower Permian Nura Nura Member of the Poole Sandstone, Fitzroy Basin, Western Australia; based on Bur. Min. Res. C.P.C. holotype 1773, at a conch diameter of 12 mm. and a whorl height of 5.5 mm.
B. *P. postsimense* Ruzhencev. From the late Sakmarian Stage (Sterlitamakian) of the Southern Urals; at a diameter of slightly less than 25 mm. and a whorl height of 11.0 mm. (from Ruzhencev, 1951, p. 170, fig. 59b).

top of the generic range and suggest that the containing beds should be correlated with the Sterlitamakian. *Propopanoceras ruzhencevi* is unlike typical species of *Popanoceras*, as the prongs of the ventral lobe are bifid and are only about 65% as wide as the corresponding first lateral lobe.

Occurrence.—The holotype is from near the top of the Nura Nura Member of the Poole Sandstone. The type locality is 1.6 miles southwest of Paradise Homestead, at 18° 02½′ S., 124° 31′ E., on Nura Nura Ridge in the Mt. Wynne area of the Fitzroy Basin of Western Australia. The paratype is from the same general area and possibly from the identical locality. *Propopanoceras ruzhencevi* is found associated with *Metalegoceras striatum*, *M. clarkei*, and *Thalassoceras wadei*, together with a sparse fauna of other molluscs, bryozoans and brachiopods. The Nura Nura Member is correlated with the Callytharra Formation and the Fossil Cliff Formation (Teichert, 1941, p. 390). It is referred to the upper part of the Sakmarian Stage (Sterlitamakian).

Repository.—Holotype 1773 and paratype 1774 are lodged with the Commonwealth of Australia Bureau of Mineral Resources, Canberra.

POPANOCERAS sp. indet.
Pl. 83, fig. 10

Description.—A single representative of this species is known to the authors. It is a poorly preserved discoidal involute internal mold consisting of phragmocone and one whorl of the body chamber. The maximum diameter is about 26 mm. At this diameter, the umbilicus has a diameter of 4½ mm., height and width of whorl about 13 mm. and 8½ mm. The whorl cross-section is somewhat rectangular, for the flanks are almost flat and approximately parallel to each other. Numerous delicate transverse striae form a low fold on the dorsolateral zones of the conch and swing posteriorly to outline a rounded sinus ventrolaterally, a low salient near the ventrolateral shoulder, and probably a deep ventral sinus. Constrictions are represented by four shallow elongate depressions across the medial and dorsal portions of the flanks, on the adapical quarter volution of the body chamber. These constrictions are parallel to the transverse lirae but are not apparent ventrolaterally or on the venter.

Only the saddles of the ultimate suture are discernible. The ventral lobe is broad and subdivided by a high secondary saddle. The crests of four pairs of simple pear-shaped external lateral saddles appear on the ventrolateral area and flanks. These saddles are associated with the first four lateral lobes, but additional elements are certainly present across the dorsolateral and umbilical portions of the conch.

Comparisons.—Cross-section, surface sculpture, and form of the suture in this specimen indicate reference to the Popanoceratidae. The form of the saddles intimates that the lateral lobes are fan-shaped; this feature, together with the localized nature of the constrictions, suggests relationship with advanced species of *Popanoceras* (Ruzhencev, 1951, p. 161).

Occurrence.—The single representative of this species is from an area 0.45 miles on a bearing of 103° from Wandagee Hill Trigonometrical Station, at 23° 50′ 00″ S., 114° 27′ 05″ E., in the Carnarvon Basin of Western Australia. It is probably from near the top of Teichert's Coolkilya Greywacke. The parent horizon is 230 feet below the top of the Coolkilya Greywacke as this formation is defined by Condon (1954), in beds assumed to be of lower Guadalupian age. Other ammonoids from the upper beds of the Coolkilya Greywacke include *Agathiceras applanatum* and *Pseudogastrioceras goochi*.

Repository.—Figured specimen 1775 is lodged with the Commonwealth of Australia Bureau of Mineral Resources, Canberra.

Family ADRIANITIDAE Schindewolf, 1931

Systematics of this family involve considerable uncertainty. Ruzhencev (1950b, p. 196–204) gave a detailed review of the group and recognized sixteen component genera and subgenera. Miller & Furnish (1957b, p. 66–67) placed in synonymy many of the taxa listed by Ruzhencev, and they included three additional genera in the family. Each of the major taxa referred to this family will be considered, as they have some bearing on the identity of Australian species.

Undoubted ancestral adrianitids are recognized in the Pennsylvanian. *Emilites*

Ruzhencev, 1938 (type: *Paralegoceras incertum* Böse, 1919, OD) occurs in the uppermost Pennsylvanian of Texas and the Urals; it differs from Lower Permian representatives of the family by its simpler suture. An even more primitive species, the type of *Dunbarites* Miller & Furnish, 1940 (*Paralegoceras rectilaterale* Miller, 1930, OD) is known from earlier Pennsylvanian strata in Texas and Oklahoma. Both genera developed two pairs of lateral lobes but are markedly different in the form of the conch. Together they constitute the subfamily Dunbaritinae of Miller & Furnish, 1957.

The genus *Crimites* Toumansky, 1937 (type: *Agathiceras Krotowi* Karpinsky, 1889; ND Glenister & Furnish) is the oldest member of the Adrianitinae. The type species has been regarded hitherto as *C. pamiricus*, listed by the original author but not validated until twelve years later (Toumansky, 1949, p. 72); two additional *nomina nuda* and four established species were also listed originally. Under the 1953 Copenhagen Decisions on Zoological Nomenclature (Proposal 130, p. 70) one of the validly published names must serve as type. Karpinsky's species is now one of the better known representatives (Ruzhencev, 1956, p. 249–250, pl. 39, figs. 3,4). No change in the general concept of the genus is involved. *Crimites* is spherical in conch outline and possesses three pairs of lobes, both external and internal. Its sutural formula is:

$$(V_1V_1)LUU^2 \cdots U^2U^1ID$$

The genus is widespread in the Lower Permian and extends into the early Upper Permian.

Artinskian adrianitids are rare and little diversified compared with those in younger strata. *Neocrimites* Ruzhencev, 1940 (type: *Adrianities fredericksi* Emeliancev, 1929, OD) and *Texoceras* Miller & Furnish, 1940 (type: *Agathoceras texanum* Girty, 1908, OD) make their appearance in rocks of this age; the former is widespread and has an extended range into the Guadalupian, whereas *Texoceras* is restricted to the Bone Spring Formation of West Texas. Both genera are characterized by subglobular form and reticulate sculpture. *Texoceras* forms three pairs of external lateral lobes and is virtually the only adrianitid with rounded mature lobes. As a subgenus of *Neocrimites* Ruzhencev proposed (1950b, p. 202) *Metacrimites* (type: *Adrianities newelli* Miller & Furnish, 1940, OD) for species in which there are four external and three internal pairs of lateral lobes. Examination of the types, as well as other material now available, suggests that *Metacrimites* possesses no basic differences from *Neocrimites* and should not be distinguished as a separate subgenus.

Wherever adrianitids have been found abundantly, they show an unusually large degree of variation in comparison to other families of Permian ammonoids. This group constitutes one of the most common elements of the Sosio Limestone, from which Gemmellaro originally distinguished fourteen species at essentially one locality. He differentiated three adrianitid genera plus one subgenus; eight additional genera or subgenera have since been proposed to include Sosio species, and undescribed collections now available to us contain several unnamed variants of comparable magnitude. Whatever the real systematic value of these variations, a smaller number of broader groupings can be recognized.

Adrianites Gemmellaro, 1887 (type: *A. elegans* Gemmellaro, 1887, OD) is characterized by subglobular shape and moderately small umbilicus. The shell surface has prominent longitudinal sculpture and weaker transverse growth lamellae. Six or seven external lateral lobes appear in the mature suture. Practically all the species originally assigned to *Adrianites* have been referred subsequently to new genera. *A. isomorphus* Gemmellaro, retained in the original genus by Ruzhencev (1950, p. 204), is somewhat intermediate in conch proportions between the type of the genus and the forms identified as the subgenus *Neocrimites* (*Sosiocrimites*) Ruzhencev, 1950 (type: *A. insignis* Gemmellaro, 1887, OD). The type species of *Sosiocrimites* differs from typical *Adrianites* only in the somewhat smaller umbilicus, more nearly globular form, and less arcuate trace of the suture. Irrespective of the intermediate forms, these features are probably of no more than specific rank. Another similar species (*A. kingi* Gemmellaro, 1887, OD) serves as the type of the subgenus *Aricoceras* (*Neoaricoceras*) Ruzhencev, 1950.

It differs from *A. insignis* in the lack of longitudinal lirae, although growth lamellae are conspicuous.

Another group of adrianitids is characterized by relatively few elements in the suture, only four or five lateral lobes being developed. *Epadrianites* Schindewolf, 1931 (type: *Agathiceras timorense* Boehm 1907, OD) was proposed to include globose forms with relatively wide umbilici and strongly developed closely spaced lirae. *Basleoceras* Ruzhencev, 1950 (type: *Agathiceras beyrichi* Haniel, 1915, OD) differs from *E. timorense* only in the wide spacing of the lirae. Haniel (1915, p. 84) stated that *Agathiceras beyrichi* is relatively rare in comparison to the common *A. timorense*, and intermediate forms are known (Haniel, 1915, pl. 50, fig. 14). *Aricoceras* Ruzhencev, 1950 (type: *Adrianites ensifer* Gemmellaro, 1887, OD) and the subgenus *Aricoceras* (*Metaricoceras*) Ruzhencev, 1950 (type: *Agathiceras cancellatum* form. *discoidalis* Haniel, 1915, OD) have smaller umbilici than typical *Epadrianites* and possess reticulate surface sculpture. We are unable to recognize any stable combination of morphologic features which allows satisfactory distinction of these four taxa from each other or from the group of species referred to *Neocrimites*. At least *Aricoceras* and *Metaricoceras* should be regarded as synonyms of *Neocrimites*. *Epadrianites* can perhaps be distinguished by its larger umbilicus.

Gemmellaro distinguished a small evolute adrianitid species as the separate genus *Doryceras* (type: *D. fimbriatum* Gemmellaro, 1887, OD). The relatively simple suture forms only three pairs of lateral lobes, and the small number of elements is probably controlled by the restricted cross sectional area. All the specimens referred to this genus by Gemmellaro are small, about 10 mm. diameter, and they may well be immature representatives of superficially dissimilar larger forms. The type species lacks longitudinal lirae, but an additional Sicilian species, *D. stuckenbergi* Gemmellaro, 1888, exhibits reticulate sculpture. *Pseudagathiceras* Schindewolf, 1931 [type: *Agathiceras* (*Doryceras?*) *Wichmanni* Haniel, 1915, OD] is an evolute form with prominent lirae. Otherwise this proposed genus is similar to *Doryceras* and should probably be regarded as a synonym. The sutures of species referred to *Pseudagathiceras* are slightly more complex than typical *Doryceras* but are based on larger specimens.

Sizilites Toumansky, 1937 (type: *Adrianites affinis* Gemmellaro, 1888, OD) was proposed for species which differ from typical *Pseudagathiceras* in the somewhat arcuate course of the suture. This name should be regarded as a synonym of *Doryceras*. One of the common larger adrianitids in the Sosio fauna (*Adrianites Distefanoi* Gemmellaro, 1887, OD) is the type species of *Palermites* Toumansky, 1937. It attains a diameter of over 40 mm., which is unusually large for the family. Faint longitudinal lirae are restricted to the umbilical area, and the suture forms five pairs of lateral lobes. The species shows many basic similarities to typical *Doryceras* but can be considered as a discrete extreme of this group of species.

A spectacularly extreme adrianitid, *Adrianites* (*Hoffmannia*) Gemmellaro, 1887 [type: *A.* (*H.*) *Hoffmanni* Gemmellaro, 1887, OD] has been regarded by Mojsisovics (1888, p. 19,20), Spath (1934, p. 16) and Ruzhencev (1957, p. 58) as a distinct subfamily or family. The conch is evolute with relatively narrow whorls and prominent umbilical ribs. The suture resembles that of many associated adrianitids and forms four pairs of lateral lobes. A close relationship of this taxon to other Upper Permian members of the Adrianitidae is apparent. *Prehoffmannia* Plummer & Scott, 1937 (type: *P. milleri* Plummer & Scott, 1937, OD) remains an enigma; the type is immature and without known sutures. There is no reason to suppose that this Pennsylvanian species is directly related to *Hoffmannia* or affines.

Clinolobus Gemmellaro, 1887 (type: *C. Telleri* Gemmellaro, 1887, OD) was based originally on only three small specimens. Greco (1935, p. 183) doubtfully identified the species, but extensive Sosio collections now available to us do not include any representative. This genus is characterized by a thinly lenticular evolute conch resembling late Permian paraceltitids rather than Goniatitacea. The obliquely directed sutural trace suggests the arched septal course of some adrianitids, however, and the three pairs of lateral lobes are somewhat

similar to those in evolute members of the family. The true relationships cannot be regarded as established without further study. The Clinolobinae Miller & Furnish, 1957, was erected for this one genus.

Genus NEOCRIMITES Ruzhencev, 1940

Type species.—*Adrianites fredericksi* Emeliancev, 1929, p. 150, pl. 51, figs. 10–17, text-figs. 5–8.

Diagnosis.—Shell spherical to subdiscoidal, involute; umbilicus narrow or closed. Reticulate sculpture formed by longitudinal lirae and transverse growth lamellae. Ventral lobe narrowly bifid; four or five pairs of lateral lobes, plus one or more pairs of lobes across umbilical wall. The typical sutural formula is:

$$(V_1V_1)LUU^2U^3U^4U^5U^6;U^4U^3U^2ID$$

but we are including somewhat less complex forms in the genus.

Distribution.—*Neocrimites* makes its first known appearance in Baigendzhinian (Artinskian) strata, and extends into the late Guadalupian. In addition to the type, which is known from the Artinskian of the Urals, the genus includes *Waagenia koswae* Krotow from the same general horizon and locality, *Adrianites nalivkini* Toumansky from the Lower Permian of Pamir, *A. newelli* Miller & Furnish from the Leonardian of Texas and Coahuila, *A. defordi* Miller & Furnish from the Leonard Formation of Texas, *Agathiceras cancellatum* form. *discoidalis* and *globosa* Haniel from the Bitauni and Basleo beds of Timor, *Adrianites ensifer* Gemmellaro from the Sosio Limestone of Sicily, *A. adamsi* Miller & Furnish from the Word Formation of Texas, *A. plummeri* Miller from the early Guadalupian of Coahuila, *A. dunbari* Miller & Furnish from the late Guadalupian of Coahuila, *A. warreni* Miller & Crockford from the Cache Creek Group of British Columbia, *Neocrimites* sp. described herein from the Artinskian Coyrie Formation of Western Australia, and *N. meridionalis* Teichert & Fletcher from the Branxton Subgroup of New South Wales.

Discussion.—The affinites of *Neocrimites* are considered under the familial heading. The present authors regard *Metacrimites*, *Aricoceras*, and *Metaricoceras* (Ruzhencev, 1950b, p. 202–203) as synonyms.

NEOCRIMITES MERIDIONALIS
Teichert & Fletcher, 1943
Pl. 86, figs. 6–9; text-fig. 16A

Goniatites (Prolecanites?) micromphalus (Morris) ETHERIDGE JR., 1894, Rec. Geol. Survey New South Wales, v. 4, pt. 1, p. 36–37, pl. 7, figs. 9,12,14 (not 10,11,13).

Adrianites (Neocrimites) meridionalis TEICHERT & FLETCHER, 1943, Australian Museum, Rec., v. 21, no. 3, p. 161–162, pl. 11, figs. 1–4, text-fig. 3.

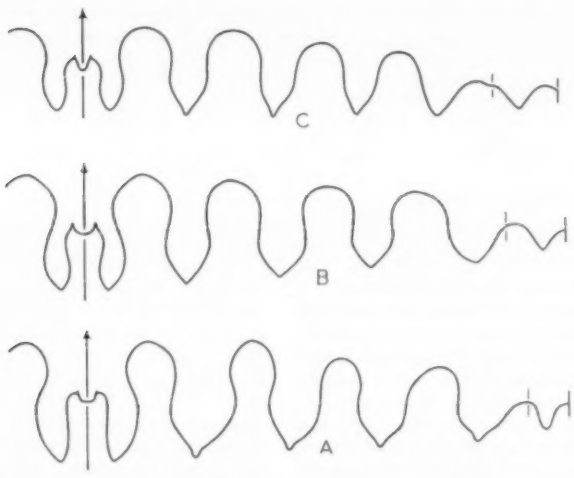
Aricoceras (Aricoceras) meridonale (Teichert & Fletcher) RUZHENCEV, 1950, Acad. Sci. U.S.S.R., Paleont. Inst., Pub., v. 29, p. 203.

Description.—The single known representative of this species is a well preserved phragmocone which retains a small portion of the body chamber. Conch measurements and proportions are listed in Table 9. Ornamentation consists of numerous delicate longitudinal lirae and slightly coarser transverse growth lamellae. The growth lamellae form an extremely shallow sinus across the flanks, a low fold on the ventrolateral flanks, and a shallow sinus across the venter.

Shell contours are illustrated on the accompanying plate and the external suture in Text-figure 16A. The internal suture is not visible.

Comparisons.—Adrianitids vary considerably in the number of elements in the mature suture and in the nature of the septal crenulations which join the external and internal lobes. The internal suture of *Neocrimites meridionalis* could only be obtained by destroying part of the single available specimen. As a result, detailed comparisons with other species of *Neocrimites* can not be made. The eastern Australian species is more compressed than most other species of the genus, and this suggests that it belongs in one of the geologically younger groups of the family (Ruzhencev, 1950b, p. 201). The closest resemblances are with some of the Upper Permian adrianitids from the Basleo beds of Timor. However, the sutural contours of most of these Timorian species are also known incompletely.

Occurrence.—The holotype of this species came from the Maitland Colliery Company's shaft, near Farley, in the Sydney Basin of New South Wales. It was collected "at a horizon a few hundred feet above the



TEXT-FIG. *16*—Diagrammatic representations of external sutures of *Neocrimites*.

A. *N. meridionalis* Teichert & Fletcher. From the Branxton Subgroup, Sydney Basin, New South Wales; based on Australian Museum holotype F35732, at a conch diameter of 27 mm., a whorl width of approximately 17 mm. and a whorl height of approximately 13½ mm.

B. *N.* sp. From the Lower Permian Coyrie Formation, Carnarvon Basin, Western Australia; based on Bur. Min. Res. C.P.C. figured specimen 1776, at a conch diameter of approximately 14 mm., a whorl width of approximately 14 mm. and a whorl height of approximately 7 mm.

C. *N. fredericksi* (Emeliancev). From the Lower Permian (Baigendzhinian) sediments of the Ural Mountains; at a conch diameter of slightly less than 20 mm., a whorl height of 9.6 mm. and a whorl width of 17.5 mm. (from Ruzhencev, 1956, p. 257, fig. 97c).

Greta Coal Seam" (Teichert & Fletcher, 1943, p. 161), from the Branxton Subgroup near the bottom of the Maitland (Upper Marine) Group. *Neocrimites* is unknown in beds older than Baigendzhinian Substage or younger than late Guadalupian Stage. General floral and faunal studies suggest a Baigendzhinian age for the known occurrence of *Neocrimites meridionalis*.

Repository.—Holotype F35732 is lodged in the Australian Museum, Sydney.

NEOCRIMITES sp.
Pl. 83, figs. 7,8; pl. 86, figs. 4,5;
text-fig. 16B

Description.—Two specimens of *Neocrimites* are known from Western Australia; their unsatisfactory preservation does not allow confident specific assignment. They are probably conspecific, but the dissimilarity in preservation of the two forms makes detailed comparisons impossible. Figured specimen 1777 is a small fragment of the outer whorl of a phragmocone, together with an external mold of additional portions of the same whorl. Exact shell proportions can not be determined from the specimen, but the whorl is broad and depressed. A reticulate ornamentation is produced by strong longitudinal lirae and weaker growth lamellae; the latter are slightly sinuous, forming a broadly rounded ventral fold, a shallow rounded sinus across the flanks and a low fold close to the umbilical shoulder. The suture consists of a bifid ventral lobe, four lateral lobes, an unknown number of lobes across the umbilical wall, four dorsolateral lobes, and a dorsal lobe. Each of the external lobes is situated opposite a corresponding internal lobe and is joined to it by a direct septal crenulation. The first three dorsolateral lobes and the first three external lateral lobes appear to be bilaterally symmetrical, whereas the fourth dorsolateral lobe and the fourth external lateral lobe are asymmetric. The septum is

TABLE 9—DIMENSIONS (IN MM.) AND PROPORTIONS OF THREE SPECIES OF *Neocrimites*

	D	H	W	U	H/D	W/D	U/D
N. meridionalis Teichert & Fletcher (holotype)	31.1	15.5	19.7	3.6	0.50	0.63	0.11
N. sp. figured specimen 1776	11.5	6.5	12	1	0.57	1.0	0.1
N. fredericksi (Emeliancev) Ruzhencev, 1956	10.4	5.4	11.4	1.3	0.52	1.10	0.13

not preserved across the umbilical wall.

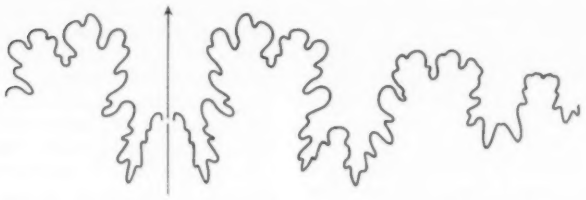
Figured specimen 1776 is a phragmocone which has been eroded to approximately the plane of symmetry. The remaining half of the specimen is well preserved, except for the complete removal of the shell. The internal mold is free of ornamentation. Conch dimensions are difficult to estimate and the figures given in Table 9 are approximations. The specimen originally retained a full whorl of body chamber and attained a maximum shell diameter of 27 mm. Most of the body chamber was removed in order to exhibit the external suture of the preceding whorl. It is possible that the original diameter represented the maximum size attained by the specimen, as the end of the shell was observed to correspond with a shallow constriction and a terminal flare.

The ventral lobe of the external suture is subdivided into a pair of narrow curved prongs by a secondary ventral saddle of moderate height. The first three external lateral lobes are tongue-shaped, pointed, and almost symmetrical. The fourth external lateral lobe is shallow, wide, and conspicuously asymmetric. It is situated on the dorsolateral flanks, and is succeeded by a low saddle across the umbilical shoulder and an obtusely angular shallow lobe across the umbilicus.

Comparisons.—*Neocrimites* sp. is similar to *N. fredericksi* from the Baigendzhinian Substage of the Aktyubinsk District in the Southern Urals. The external sutures of the two species appear to be almost identical, but the preservation of the Australian material does not permit useful detailed comparisons of shell proportions and ornamentation. Close affinities with several of the globose Timorian adrianitids are also apparent. *Neocrimites globosus* (Haniel, 1915, p. 76–77, pl. 50, fig. 1), from both the Bitauni and Basleo beds of Timor, is closely comparable in ornamentation and shell form. Minor differences in the published representations of the sutures of the Timorian and Western Australian specimens are apparent, but the two forms may yet prove to be conspecific. The external sutures of the eastern Australian species, *N. meridionalis* Teichert & Fletcher from the Branxton Subgroup of the Maitland (Upper Marine) Group of New South Wales, are closely comparable with those of *N.* sp., but the compressed whorl section of *N. meridionalis* permits differentiation.

Occurrence.—Figured specimen 1777 is from 4.95 miles on a bearing of 119° from Donelly's Well, and 4.7 miles on a bearing of 236° from Moogooree Homestead, at 24° 06′ 06″ S., 115° 08′ 04″ E., on Moogooree Station in the Carnarvon Basin of Western Australia. It was collected from 485 feet above the base of the Coyrie Formation. Figured specimen 1776 is from 2000 feet north of the Mt. Sandiman Woolshed (24° 23′ 22″ S., 115° 16′ 44″ E., Military Grid Reference 1,964,670 yd. N., 320,000 yd. E., Carnarvon Topographic Series Sheet 10), on Mt. Sandiman Station in the Carnarvon Basin of Western Australia. It was collected from the Coyrie Formation, at about one-third the outcrop width from the base of the unit. *Neocrimites* sp. is found in the same formation as *Propinacoceras* n. sp., together with a varied marine fauna (Condon, 1954, p. 63). These ammonoids suggest that the Coyrie Formation should be correlated with either the lower Baigendzhinian Substage or the Aktastinian Substage of the Artinskian Stage.

Repository.—Figured specimens 1776 and 1777 are lodged with the Commonwealth of



TEXT-FIG. 17—Diagrammatic representation of part of the external suture of gen. indet., from the Lower Permian Nura Nura Member of the Poole Sandstone, Fitzroy Basin, Western Australia; based on Uni. W. A. figured specimen 35778, at a conch diameter of approximately 12 mm.

Australia Bureau of Mineral Resources, Canberra.

Ammonitiform, family and gen. indet.
Pl. 80, figs. 8,9; text-fig. 17

Description.—A single representative of this species is known to the authors. It is a well preserved limonitized mold of a moderately evolute phragmocone of 19 mm. maximum diameter. The whorls are uniformly rounded across the umbilical shoulder, flanks and venter; they are slightly depressed and circular in cross-section, and are moderately impressed dorsally. The umbilicus has a maximum diameter of 5 mm.; the whorl has a maximum height of 8 mm. and a corresponding width of 9½ mm. Only two complete whorls are discernible as the inner volutions are imperfectly preserved. The internal mold is free of ornamentation except for six shallow constrictions on the ultimate whorl. These constrictions are virtually straight, but they form an extremely shallow sinus across the flanks and a low fold on the venter.

The complete external suture is not available, but the first three external saddles and intervening lobes may be reconstructed with confidence from a number of partial sutures. All of the observable saddles and lobes are strongly dissected by secondary elements (Text-fig. 17). The ventral lobe is divided into two narrow dentate prongs by a low secondary ventral saddle. Both the first and second lateral saddles are wider than the corresponding lobes. It is almost certain that three additional pairs of divided lobes and intervening saddles are present across the dorsolateral flanks and umbilical shoulder, but they can not be traced with certainty. A study of the septa indicates the presence of two pairs of dorsolateral lobes and a dorsal lobe. The septal necks are retrochoanitic and of moderate length.

Discussion.—To the best of our knowledge the described specimen is of Lower Permian age, but the possibility of derivation from considerably younger strata still exists. This problem is considered in detail under the "occurrence" heading. The only reason to question the authenticity of a Lower Permian age for the specimen is that it is of a Mesozoic type and is not related to any known Permian form.

From time to time diverse morphological ammonoid types have been found unexpectedly in the late Paleozoic. For example, the existence of a form such as *Prodromites* in the Lower Mississippian could not have been reasonably anticipated on the basis of the morphology and phylogeny of associated ammonoids. However, the well known case of *Schuchertites*, a Cretaceous engonoceratid described as a new Carboniferous taxon by Smith (1903, p. 48–51, pl. 21, figs. 20–22) "should serve as a warning" (Spath, 1934, p. 14).

The ammonitic form and relationship of elements in the suture of the Western Australian specimen are of a generalized type which occurs in a multitude of familial groups throughout the Mesozoic. Within the Permian the combination of a low secondary ventral saddle, subdivided sutural elements, and retrochoanitic septal necks is restricted to the Xenodiscidae of the Upper Permian; no known representative of this family has an ammonitic suture. The morphological characters in the Western Australian species can perhaps be duplicated in known Mesozoic taxa. However, a

cursory examination indicates that there are apparent differences in each case.

While the possibility of derivation of the specimen from Mesozoic strata can not be eliminated, we believe that the evidence for a Lower Permian age is sufficiently good to warrant description of the material. It is hoped that publication of the description will stimulate interest in the problem and result in the accumulation of conclusive data.

Occurrence.—The single representative of this species (Uni. W.A. figured specimen 35778) bears A. Wade's field number "A108," and the accompanying label indicates that it came from Nura Nura Ridge in the Fitzroy Basin of Western Australia. It is a small completely limonitized specimen, and was associated in a single collection box (Geology Repository, Uni. W.A.) with a large fauna of identically preserved invertebrates. Information on the parent formation was not given with the locality data. However, J. M. Dickins (written communication, February 3, 1958) has studied the large associated fauna of pelecypods, gastropods, spiriferid brachiopods and straight nautiloids, and he has concluded "without hesitation that the fauna is from the Nura Nura Member" of the Poole Sandstone. This formation assignment is compatible with the type of preservation and the known distribution of formations in the Mt. Wynne area.

From the information given above, there can be little doubt that the fauna associated in the repository collection with the ammonoid is of Lower Permian age. It remains for us to test the possibility that the specimen represents a contamination of this Lower Permian fauna.

Nura Nura Ridge is formed of Poole Sandstone and is surrounded by Permian strata. The nearest exposures of undoubted Mesozoic strata are over 30 miles to the south of Nura Nura Ridge, although sediments of possible Lower Triassic age crop out some 5 miles to the north. The physiography of Nura Nura Ridge precludes transportation of the specimen by natural agencies, and there is no reason to suspect that it was transported by human agency. Similarly preserved limonitic ammonoids are not known from the Mesozoic of the Fitzroy Basin, but the possibility that the specimen is a repository contamination from foreign collections can not be eliminated entirely. The information presented herein thus indicates convincingly, but not conclusively, that the ammonoid is from the Nura Nura Member of the Poole Sandstone, and is therefore of uppermost Sakmarian age.

Repository.—Figured specimen 35778 is lodged with the Department of Geology, The University of Western Australia.

ADDENDUM

Two significant additions have become available from Western Australia since completion of this manuscript. One specimen (Univ. W.A. 45246) was secured from type Fossil Cliff Formation on the west bank of North Irwin River, in the Mingenew area of the Perth Basin. It is excellently preserved, and represents an undescribed species of the metalegoceratid genus *Juresanites*. There are ten whorls of phragmocone plus a volution of body chamber, although the maximum diameter is only 31 mm. The large number of volutions indicates maturity, but size attained is relatively small for this family. Corresponding measurements for height, width, and umbilicus are: 8½, 19, and 17½ mm. Moderately conspicuous convex growth lamellae and transverse constrictions exist on the exterior of the shell and are reflected on the internal mold. The sutures display metalegoceratid ontogenetic development but differ from known species in proportions, particularly the shallowness of lateral (L) in comparison with the ventral lobe (V_1) and of the primary umbilical lobe (U_1) related to its ventral subdivision (U_2).

Discovery of *Juresanites* supports the Sakmarian age assignment of the Fossil Cliff Formation, as the genus is restricted to Asselian and Sakmarian strata. Closest similarities are with Sakmarian metalegoceratids from the southern Urals; several species exhibit comparable conch ratios, but the suture in this specimen is unique.

The second specimen is a poorly preserved fragmentary ammonoid (Uni. W.A. 45249) which cannot be identified with certainty. It is from the same general area as the new species of *Juresanites* but from a

higher stratigraphic level, the Mingenew Formation. The locality is Enanty Hill, near Mingenew.

The form of the conch combined with the shape of the aperture relate this specimen to the family Xenodiscidae. Size and general proportions, plus lack of conspicuous ornament suggest *Xenaspis* rather than any other known genus. Available portions of the septa tend to confirm this assignment.

This ammonoid is about 55 mm. in diameter and at least the outer one-fourth volution is non-septate. There are apparently six volutions, but the innermost portion is obscure. The whorls are flattened laterally and rounded ventrally; the body chamber is about 17 mm. in height, 12 mm. in width, and is impressed 3 mm. dorsally. A fraction of the ultimate septate volution is present but crushed. Growth lines reflected on the internal mold form ventrolateral sinuses; the ventral salient is prominent and the lateral salients are relatively low.

Xenaspis and closely related forms occur in the upper Guadalupian and Dzhulfian of several areas. The genus is found associated with *Cyclolobus* in the Punjab, the Himalayas, and Madagascar. Other recorded occurrences are less certain but are of late Permian age. The related and somewhat similar Paraceltitidae Spath (Miller & Furnish, 1940, p. 63) are likewise characteristic of the Upper Permian, but a single species of *Paraceltites* is known from the uppermost Lower Permian of West Texas. No other group of Permian ammonoids is known to have closely similar conch form.

REFERENCES

ARKELL, W. J., KUMMEL, BERNARD & WRIGHT, C. W., 1957, Mesozoic Ammonoidea, *in* Arkell *et al.*, Ammonoidea: Treatise Invert. Paleontology, R. C. Moore, ed., Pt. L, Mollusca 4, p. 80–490.

BÖHMERS, J. C. A., 1936, Bau und Struktur von Schale und Sipho bei permischen Ammonoidea: 125 p., 2 pls., Univ. Amsterdam.

BOOKER, F. W., 1955, New South Wales; *in* Hill *et al.*, Contributions to the correlation and fauna of the Permian in Australia and New Zealand: Geol. Soc. Australia, Jour., v. 2 (1954), p. 92–95.

BÖSE, EMIL, 1919, The Permo-Carboniferous ammonoids of the Glass Mountains, west Texas, and their stratigraphical significance: Texas Univ. Bull. 1762 (1917), 241 p., 11 pls.

BRANSON, C. C., 1948, Bibliographic index of Permian invertebrates: Geol. Soc. America, Mem. 26, 1049 p.

CHAO, KINGKOO, 1954, Permian cephalopods from Tanchiashan, Hunan: Acta Palaeontologica Sinica, v. 2, no. 1, p. 1–58, pls. 1–7 [in Chinese and English].

——, 1955, Some Permian ammonoids from Kwangsi and their significance: Acta Palaeontologica Sinica, v. 3, no 2, p. 135–158, pls. 1,2 [in Chinese and English].

CLIFTON, R. L., 1942, Invertebrate faunas from the Blaine and the Dog Creek formations of the Permian Leonard Series: Jour. Paleontology, v. 16, p. 685–699, pls. 101–104.

CONDON, M. A., 1954, Progress report on the stratigraphy and structure of the Carnarvon Basin, Western Australia: Comm. Australia Bur. Min. Res., Rept. 15, 163 p., 3 pls.

DAVID, T. W. E., 1950, The geology of the Commonwealth of Australia; W. R. Browne, ed.: v. 1, xx+747 p., London, Edward Arnold.

—— & SÜSSMILCH, C. A., 1931, Upper Paleozoic glaciations of Australia: Geol. Soc. America, Bull., v. 42, p. 481–522.

DE VERNEUIL, ÉDOUARD, 1845, Geologie de la Russie d'Europe et des Montagnes de l'Oural (by Murchison, de Verneuil, and Keyserling): v. 2, Paléontologie (by de Verneuil), 512 p., 43 pls.

DUN, W. S. & DAVID, T. W. E., 1923, Notes on the occurrence of *Gastrioceras* at the Irwin River Coal-field, W. A., and a comparison with the so-called *Paralegoceras* from Letti, Dutch East Indies: Royal Soc. New South Wales, Jour. Proc., 1922, v. 56, p. 249–252, pls. 11–13.

EMELIANCEV, T., 1929, Artinskian cephalopods from the Polyudovsk Ridge district in the Urals: Comité géol. (Leningrad) Bull., t. 48, no. 8, p. 145(1229)–152(1236), pl. 51 [in Russian].

ETHERIDGE, R., JR., 1894, Palaeontologia Novae Cambriae Meridionalis; Occasional descriptions of New South Wales fossils, No. 1: Rec. Geol. Survey New South Wales, v. 4, pt. 1, p. 32–37, pl. 7.

——, 1907, Description of Carboniferous fossils from the Irwin River, collected by Mr. C. F. V. Jackson: Geol. Survey W. Australia, Bull. 27, p. 26–37, pls. 3–10.

FRÉDÉRIX, GEORGE, 1915, La faune Paléozoique supérieure des environs de la ville de Krasnoouſimsk: Mém. Comité Géol., n. sér., livr. 109, 117 p., 10 pls.

GEMMELLARO, G. G., 1887, La fauna dei calcari con *Fusulina* della valle del fiume Sosio nella provincia di Palermo: Gior. Sci. nat. ed econ., v. 19, p. 1–106, pls. 1–10; App., 1888, *ibid.*, v. 20, p. 9–36, pls. A–D.

GERTH, H., 1950, Die Ammonoideen des Perms von Timor und ihre Bedeutung für die stratigraphische Gliederung der Permformation: N. Jahrb. Mineralogie etc., Abh., Bd. 91, Abt. B, p. 233–320.

GIRTY, G. H., 1908, The Guadalupian fauna: U. S. Geol. Survey, Prof. Paper 58, 651 p., 31 pls.

GLENISTER, B. F., 1955, Cephalopoda; *in* Hill *et al.*, Contributions to the correlation and fauna of the Permian in Australia and New Zealand. Geol. Soc. Australia, Jour., v. 2 (1954), p. 102–103.

GORDON, MACKENZIE, JR., 1957, Mississippian cephalopods of northern and eastern Alaska: U. S. Geol. Survey, Prof. Paper 283, 61 p., 6 pls.

GRABAU, A. W., 1923–1924, Stratigraphy of China; Part 1, Palaeozoic and older: 528 p., 6 pls., China Geol. Survey, Peking.

——, 1931, The Permian of Mongolia: Natural History of Central Asia; C. A. Reeds, ed.; v. 4, 665 p., 35 pls., Am. Mus. Natural History.

GRECO, BENEDETTO, 1935, La fauna permiana del Sosio conservata nei Musei di Pisa, di Firenze e di Padova; Parte 1: Palaeontographia Italica, v. 35, p. 101–190, pls. 12–15.

GUPPY, D. J., LINDNER, A. W., RATTIGAN, J. H. & CASEY, J. N., 1958, The geology of the Fitzroy Basin, Western Australia: Comm. Australia Bur. Min. Res., Bull. 36, 116 p., 10 pls.

HANIEL, C. A., 1915, Die Cephalopoden der Dyas von Timor: Paläontologie von Timor, Lief, 3, Abh. 6, p. 1–153, pls. 46(1)–56(11).

HARKER, PETER & THORSTEINSSON, RAYMOND, 1960, Permian rocks and faunas of Grinnell Peninsula, Arctic Archipelago: Geol. Survey Canada, mem. 309, 89 p., 25 pls.

HAUG, EMIL, 1911, Traité de Géologie; Deuxième partie, les Périodes géologiques; p. 539–928, Paris.

HILL, DOROTHY, 1952, The Gondwana System in Queensland: Symposium Sér. Gondwana; Curt Teichert, ed.: p. 35–49; XIX^{e} Cong. Géol. Internat., Alger, 1952.

——, DENMEAD, A. K., *et al.*, 1960, The geology of Queenlands: Geol. Soc. Australia, Jour., v. 7, 474 p., 8 pls.

HOSKING, L. F. V., 1931, Fossils from the Wooramel District, Western Australia: Royal Soc. W. Australia, Jour., v. 17 (1930–1931), p. 7–52, pls. 3–13.

HUDSON, R. G. S., 1957, Discussion on 'Basic paleogeography of Gondwanaland during the Late Paleozoic and Mesozoic eras' by L. C. King: Geol. Soc. London, Proc., no. 1549, p. 74.

JACK, R. L. & ETHERIDGE, R. JR., 1892, The geology and palaeontology of Queensland and New Guinea: xxx+768 p., 68 pls., Queensland Govt. Printer, Brisbane.

KARPINSKY, A. P., 1889 [?1890], Über die Ammoneen der Artinsk-Stufe und einige mit denselben verwandte carbonische Formen: Acad. Imp. Sci. St.-Pétersbourg, Mém., sér. 7, t. 37, no. 2, p. 1–104, pls. 1–5.

——, 1926, On a new species of ammonoid of the family Medlicottinae; on the relationship between genera of this family, and on the ontogeny and phylogeny of the Prolecanitidae: Soc. Paléont. Russie Annuaire, t. 4, p. 1–19.

KING, P. B., 1942, Permian of West Texas and southeastern New Mexico: Amer. Assoc. Petroleum Geologists, Bull., v. 26, p. 535–763.

LIKHAREV, B. K., *et al.*, 1958, U.R.S.S.: Congrès Géol. Int.—Comm. Stratigraphie, Lexique Strat. Int., v. 2; fasc. 1–3, 1738 p.; fasc. 4, 564 p.

MAXIMOVA, S. V., 1940, *Juresanites*, a new genus of the family Somoholitidae: Acad. Sci. U.S.S.R., Doklady, v. 28, no. 9, p. 862–864.

McWHAE, J. R. H., PLAYFORD, P. E., LINDNER, A. W., GLENISTER, B. F. & BALME, B. E., 1958, The stratigraphy of Western Australia: Geol. Soc. Australia, Jour., v. 4, pt. 2, 161 p., 1 pl.

MILLER, A. K., 1932, *Metalegoceras jacksoni* of the Irwin River Coalfield, Western Australia: Am. Jour. Sci., ser. 5, v. 24, p. 433–442, pl. 1.

——, 1936, A new Permian ammonoid fauna from Western Australia: Jour. Paleontology, v. 10, p. 684–688, pl. 92.

——, 1944, Part IV, Permian cephalopods; *in* R. E. King *et al.*, Geology and paleontology of the Permian area northwest of Las Delicias, southwestern Coahuila: Geol. Soc. America, Spec. Paper 52, p. 71–130, pls. 20–45.

—— & CROCKFORD, M. B., 1936, Permian cephalopods from British Columbia: Royal Soc. Canada, Trans., ser. 3, sec. 4, v. 30, p. 23–28, pl. 1.

—— & FURNISH, W. M., 1939, The Late Paleozoic ammonoid families Adrianitidae and Agathiceratidae: Paläont. Zeitschr., Bd. 21, p. 297–303.

—— & ——, 1940, Permian ammonoids of the Guadalupe Mountain region and adjacent areas: Geol. Soc. America Spec. Paper 26, 242 p., 44 pls.

—— & ——, 1954, The classification of the Paleozoic ammonoids: Jour. Paleontology, v. 28, p. 685–692.

—— & ——, 1957a, Permian ammonoids from southern Arabia: Jour. Paleontology, v. 31, p. 1043–1051, pls. 131–132.

—— & ——, 1957b, Paleozoic ammonoids, *in* Arkell *et al.*, Ammonoidea: Treatise Invert. Paleontology, R. C. Moore, ed., Pt. L, Mollusca 4, p. 11–36, 47–79.

—— & ——, 1957c, Ammonoids of the basal Word formation, Glass Mountains, West Texas: Jour. Paleontology, v. 31, p. 1052–1056, pl. 133.

—— & ——, 1957d, Permian ammonoids from Tunisia: Jour. Paleontology, v. 31, p. 705–712, pl. 83.

—— & ——, 1958, Permian ammonoids from the Colorado Plateau: Jour. Paleontology, v. 32, p. 682–683, pl. 94.

——, —— & CLARK, D. L., 1957, Permian ammonoids from western United States: Jour. Paleontology, v. 31, p. 1057–1068, pls. 133–134.

—— & WARREN, P. S., 1933, A *Propinacoceras* from North America: Am. Jour. Sci., ser. 5, v. 26, p. 295–299.

VON MÖLLER, VAL, 1879, Ueber die bathrologische Stellung des jüngeren Paläozoischen Schichtensystems von Djoulfa in Armenien: Neues Jahrbuch Mineralogie, Geologie, Paläontologie, Jahrg. 1879, p. 225–243.

MONTANARO GALLITELLI, E., 1956, Il Permiano del Sosio e suoi Coralli: Palaeont. Italica, v. 49, p. 1–98.

MORRIS, J., 1845, Fossil Fauna, Mollusca; *in* P. E. de Strzelecki, Physical description of New South Wales and Van Dieman's Land: p. 270–291, pls. 10–18; London.

NOETLING, FRITZ, 1904, Ueber *Medlicottia* Waag. und *Episageceras* n. g. aus den permischen und triadischen Schichten Indiens: N. Jahrb. Mineralogie, etc., B.-Bd. 19, p. 334–376, pls. 17–20.

OVENS, F. A. H. W. DE MAREZ, 1938, Preliminary note on the occurrence of a new ammonoid fauna of Permian age on the Island of Timor: Kon. Nederlandsche Akad. Wetensch., Proc., v. 41, p. 1122–1126.

PLAYFORD, GEOFF, 1959, Permian stratigraphy of the Woolaga Creek area, Mingenew District, Western Australia: Royal Soc. W. Australia, Jour., v. 42, p. 7–32, 3 pls.

PLUMMER, F. B. & SCOTT, GAYLE, 1937, Upper Paleozoic ammonites in Texas; The geology of Texas, Volume III; Part 1: Texas Univ. Bull. 3701, p. 1–516, pls. 1–41.

POPOW, V. N., 1958, Some Permian pelecypods, gastropods and ammonoids of the Verkhoyan: Mater. Geol. Polezn. Iskop. NE C.C.C.P., no. 12, p. 137–150, pls. 1–3 [in Russian].

RAGGATT, H. G., 1950, Stratigraphic nomenclature: Australian Jour. Sci., v. 12, p. 170–173.

——, 1953, A.N.Z.A.A.S. Standing Committee on Stratigraphic Nomenclature: Australian Jour. Sci., v. 15, p. 122–125.

——, 1956, Australian Code of Stratigraphic Nomenclature: Australian Jour. Sci., v. 18, p. 117–121.

REED, F. R. C., 1936, Some fossils from the *Eurydesma* and *Conularia* beds (Punjabian) of the Salt Range: India Geol. Survey Mem., Paleontologia Indica, n. ser., v. 23, mem. 1, p. 353–379, pls. 60–65.

RUZHENCEV, V. E., 1936, Paleontological notes on Carboniferous and Permian ammonoids: Problems Soviet Geology, v. 6, no. 12, p. 1072–1088.

——, 1937, Stratigraphical outline of the Upper-Carboniferous and Lower-Permian deposits in the Orenburg district (U.S.S.R.): Soc. Nat. Moscou Bull., sec. géol., t. 15, no. 3, p. 187–214.

——, 1938, Ammonoids of the Sakmarian Stage and their stratigraphic significance: Problems Paleontology, v. 4, p. 187–285, pls. 1–7, 19 text-figs. [introductory portions (stratigraphic part) in both Russian and English; remainder (paleontologic part) in English only].

——, 1939, A new genus *Synartinskia* from the family Medlicottiidae: Acad. Sci. U.S.S.R., Doklady, v. 25, no. 5, p. 461–464.

——, 1940a, An essay on the natural classification of some late Paleozoic ammonites: Acad. Sci. U.S.S.R., Paleont. Inst. Pub. v. 11, book 3, p. 1–134, pls. 1–6 [in Russian, with English summary].

——, 1940b, On the family Adrianitidae Schindewolf: Acad. Sci. U.S.S.R., Doklady, v. 26, no. 8, p. 837–840.

——, 1941, A new Upper Carboniferous genus *Daixites* from the family Medlicottiidae Karpinsky: Acad. Sci. U.S.S.R., Doklady, v. 30, no. 9, p. 880–883.

——, 1947, Systematics of the family Medlicottiidae Karpinsky: Acad. Sci. U.S.S.R., Doklady, n. ser., v. 61, no. 6, p. 639–642 [in Russian].

——, 1949a, Systematics and evolution of the families Pronoritidae Frech and Medlicottiidae Karpinsky: Acad. Sci. U.S.S.R., Paleont. Inst., Pub., v. 19, 204 p., 17 pls. [in Russian].

——, 1949b, Main types of evolutionary changes of the suture line in Upper Paleozoic ammonites: Acad. Sci. U.S.S.R., Paleont. Inst., Pub., v. 20, p. 183–198 [in Russian].

——, 1950a, Type section and biostratigraphy of the Sakmarian Stage: Acad. Sci. U.S.S.R., Doklady, v. 71, no. 6, p. 1101–1104 [in Russian].

——, 1950b, Upper Carboniferous ammonites of the Urals: Acad. Sci. U.S.S.R., Paleont. Inst., Pub., v. 29, 223 p., 15 pls. [in Russian].

——, 1951, Lower Permian ammonoids of the southern Urals—I; Ammonoids of the Sakmarian Stage: Acad. Sci. U.S.S.R., Paleont. Inst., Pub., v. 33, 188 p., 15 pls. [in Russian].

——, 1952, Biostratigraphy of the Sakmarian Stage in the Aktyubinsk region of Kazakhstan, U.S.S.R.: Acad. Sci. U.S.S.R., Paleont. Inst., Pub., v. 42, 87 p., 6 pls. [in Russian].

——, 1954, The Assel Stage of the Permian System: Acad. Sci. U.S.S.R., Doklady, v. 99, no. 6, p. 1079–1082 [in Russian].

——, 1955, Fundamental stratigraphical assemblages of ammonoids in the Permian System: Acad. Sci. U.S.S.R., biological ser., no. 4, p. 120–132 [in Russian].

——, 1956, Lower Permian ammonoids of the southern Urals—II; Ammonoids of the Artinskian Stage: Acad. Sci. U.S.S.R., Paleont. Inst., Pub., v. 60, 275 p. 39 pls. [in Russian].

——, 1957, Phylogenetic system of the Paleozoic ammonoids: Moscow Soc. Invest. Nature, Bull., Sec. Geology, v. 32, p. 49–64 [in Russian].

——, 1959, Classification of the superfamily Otoceratoceae: Acad. Sci. U.S.S.R., Paleont. Jour., 1959, no. 2, p. 56–67 [in Russian].

——, 1960, Ammonoid classification problems: Jour. Paleontology, v. 34, p. 609–619.

SCHINDEWOLF, O. H., 1931, Über den Ammoniten-Sipho: Preuss. Geol. Landesanst. Sitzungsber., Heft 6, p. 197–209, pl. 5.

SMITH, J. P., 1903, The Carboniferous ammonoids of America: U. S. Geol. Survey, Mon. 42, 211 p., 29 pls.

——, 1927, Permian ammonoids of Timor: Mijnw. Nederlandsch-Indië Jaarb., Jaarg. 55 (1926), Verh. 1, p. 1–91, 16 pls.

——, 1929, The transitional Permian ammonoid fauna of Texas: Amer. Jour. Sci., v. 17, ser. 5, p. 63–80.

SPATH, L. F., 1934, Catalogue of the fossil Cephalopoda in the British Museum (Natural History), Part 4, The Ammonoidea of the Trias: 521 p., 18 pls.

STOYANOW, A. A., 1910, On the character of the boundary of Palaeozoic and Mesozoic near Djulfa: Imp. Russ. Mineral. Soc., Mem., v. 47, p. 61–135, pls. 6–9.

SUN, Y. C., 1947, The uppermost Permian ammonoids from Kwangsi and their stratigraphical significance: Peking National Univ., Geol. Inst., Contr., no. 28, p. 35–49, pls. 1,2 [reprint 40th Anniv. Papers National Univ. Peking, 1939].

TCHERNOW, A. A., 1907, L'étage d'Artinsk: I, Ammonoïdés des bassins de Jaïva, de Kosva et de Tchoussovaïa, Livr. 1: Soc. Imp. Nat. Moscou, Bull., n. sér., t. 20, p. 270–401, pl. 1.

TEICHERT, CURT, 1940, *Helicoprion* in the Permian of Western Australia: Jour. Paleontology, v. 14, p. 140–149, pls. 22,23.

——, 1941, Upper Paleozoic of Western Australia; correlation and paleogeography: Am. Assoc. Petroleum Geologists, Bull., v. 25, p. 371–415.

——, 1942, Permian ammonoids from Western Australia: Jour. Paleontology, v. 16, p. 221–232, pl. 35.

——, 1944, Two new ammonoids from the Permian of Western Australia: Jour. Paleontology, v. 18, p. 83–89, pl. 17.

——, 1950, Some recent additions to stratigraphy of Western Australia: Am. Assoc. Petroleum Geologists, Bull., v. 34, p. 1787–1794.

——, 1951, The marine Permian faunas of Western Australia: Paläont. Zeitschr., v. 24, p. 76–90.

——, 1952, Carboniferous, Permian, and Jurassic in the Northwest Basin, Western Australia: Symposium Sér. Gondwana, Curt Teichert, ed.; p. 115–135, XIX• Cong. Géol. Internat., Alger, 1952.

——, 1954, A new ammonoid from the eastern Australian Permian province: Royal Soc. New South Wales, Jour. Proc., v. 87, p. 46–50, pl. 7.

——, 1957, Notes on the geology of the Carnarvon (Northwest) Basin, Western Australia: Royal Soc. W. Australia, Jour., v. 40, pt. 2, p. 65–72, pls. 1,2.

—— & FLETCHER, H. O., 1943, A Permian ammonoid from New South Wales and the correlation of the Upper Marine Series: Australian Mus., Rec., v. 21, p. 156–163, pl. 11.

—— & GLENISTER, B. F., 1952, Lower Permian ammonoids from the Irwin Basin, Western Australia: Jour. Paleontology, v. 26, p. 12–23, pls. 3,4.

THOMAS, G. A. & DICKINS, J. M., 1954, Correlation and age of the marine Permian formations of Western Australia: Australian Jour. Sci., v. 16, p. 219–223.

THOMAS, H. D., 1929, The late Palaeozoic glaciation: Nature, v. 123, p. 946–948.

TOUMANSKY, O. G., 1937a, About the representatives of the family Adrianitidae Schindewolf: Soc. Nat. Moscou, Bull., sec. géol., t. 15, p. 375–378 [in Russian, English summary].

——, 1937b, Sur des représentants d'un nouveau genre permien *Crimites:* Soc. Paléont. Russie, Ann., t. 11, p. 146–147 [in Russian].

——, 1938a, On a new genus *Tauroceras* from the Permian of Crimea and Sicily: Problems Soviet Geology, v. 8, no. 8–9, p. 145–146 [in Russian].

——, 1938b, On certain new genera of the family Popanoceratidae Hyatt: Problems Soviet Geology, v. 8, no. 12, p. 106–108 [in Russian].

——, 1949, On the Permian ammonoids of Middle Asia: Soc. Nat. Moscou, Bull., sec. géol., t. 24, p. 49–84, pls. 1–6 [in Russian].

—— & BORNEMAN, B. A., 1937, On the Permian ammonoids of Darvas: Soc. Nat. Moscou, Bull., sec. géol., t. 15, p. 104–118, pl. 1 [in Russian, English summary].

VALLANCE, H. B., 1959, New South Wales: Congrès Géol. Int.—Comm. Stratigraphie, Lexique Strat. Int., v. 6, fasc. 5b, 210 p.

WAAGEN, WILLIAM, 1880, Salt-Range fossils; *Productus* limestone fossils: India Geol. Survey Mem., Palaeontologia Indica, ser. 13, v. 1, pt. 2, p. 73–183, pls. 7–16.

WHITEHOUSE, F. W., 1925, List of fossil fauna and flora, Nebo District: Queensland Govt. Mining Jour., v. 25, no. 307, p. 474.

JOURNAL OF PALEONTOLOGY, V. 35, NO. 4, P. 737–758, PLS. 87–89, 5 TEXT-FIGS., JULY, 1961

THE AMMONITE FAMILY BINNEYITIDAE REESIDE IN THE WESTERN INTERIOR OF THE UNITED STATES

W. A. COBBAN
U. S. Geological Survey, Denver

ABSTRACT—The ammonite family Binneyitidae Reeside is represented in the Western Interior region of the United States by at least three species of *Borissiakoceras*, five species of *Binneyites*, and one species of a new genus, *Johnsonites*. The family is known only from the lower part of the Upper Cretaceous. *Johnsonites*, which is represented only by the genotype, occurs in the oldest of the Cenomanian zones of the Western Interior region. *Borissiakoceras* is found in the Cenomanian and in the lower part of the overlying Turonian. *Binneyites* has a range of about middle Turonian to lower Santonian. New species described are *Johnsonites sulcatus*, *Borissiakoceras compressum*, *Binneyites carlilensis*, *B. nodosus*, and *B. rugosus*.

INTRODUCTION

EXAMPLES of the family Binneyitidae have been among the rarest of ammonites. This may be due in part to their small size; most adults are less than 30 mm. in diameter. Specimens collected in recent years by members of the U. S. Geological Survey show that the family has a greater time span than previously known, and that representatives of the family are present in no less than twelve levels in the lower part of the Upper Cretaceous.

The holotype of *Binneyites parkensis* Reeside is in Yale Peabody Museum, in New Haven, Connecticut. The type specimen of *Borissiakoceras reesidei* Morrow is at the University of Kansas, in Lawrence, Kansas. All other specimens of the Binneyitidae figured in the present report are at the U. S. National Museum, in Washington, D. C.

Publication authorized by the Director, U. S. Geological Survey.

FAMILY CHARACTERISTICS

Reeside (1927, p. 4,5) established the family Binneyitidae for his new genus *Binneyites* represented by the single new species *B. parkensis* Reeside. A definition of the family was not given other than that of the genus, which was defined as

> "a much compressed discoid shell with subparallel flanks, truncated venter bordered by subangular shoulders, and very small umbilicus. Whorls with flanks smooth except for latest part of shell, which shows low falciform ribs; and with distant, elongated and inclined nodes on the ventrolateral shoulders. Suture with simple elements; ventral lobe small, first lateral saddle long and very narrow, simple; first lateral lobe broad, asymmetrically bifid; second lateral saddle broad, high, bifid; second lateral lobe long, narrow, asymmetrically bifid; other elements small, simple."

Basse (1952, p. 668) briefly defined the family Binneyitidae to include very involute discoid shells that have subparallel flanks, truncated venter, and simple suture. She gave the age as Cenomanian to Coniacian, and included in the family the genera *Flickia* Pervinquière, *Adkinsia* Böse, and *Neolobites* Fischer.

Wright (1952, p. 222) noted that the "Binneyitidae was established for the Coniacian *Binneyites* Reeside, whose ancestor is clearly the Turonian *Borissiakoceras* Arkhangelsky. This genus may in turn be derived from certain aberrant Acanthoceratids, probably referable to *Protacanthoceras* Spath." Later Wright (1957, p. L418) defined the family to include

> "Rather small, compressed and flat-sided forms with little ornament and peculiar suture tending to have deep, narrow, simple or even entire elements with parallel sides. The early species retain traces of ventrolateral ornament which indicate derivation from a compressed acanthoceratid, probably *Protacanthoceras*."

Wright gave the range as Upper Cenomanian to Coniacian, and included in the family only *Binneyites* and *Borissiakoceras*. In addition to these genera, Glazunova & Luppov (1958, p. 130) include *Flickia* and *Adkinsia* within the family.

The writer follows Wright in restricting the family to small discoid shells that have a peculiar suture characterized by that of *Binneyites*. In addition to the elements of

the suture tending to have parallel sides, the second lateral saddle is as high as or, more commonly, higher than the first lateral saddle. Nodes, when present, are confined to the ventrolateral shoulder. Excluded from the family are *Adkinsia*, which is globular and has umbilical tubercles; *Flickia*, which has a very high first lateral saddle; and *Neolobites*, which has an engonoceratid suture. Included in the family are *Binneyites*, *Borissiakoceras*, and a new genus, *Johnsonites*. The known age span of the family is Cenomanian to early Santonian.

GEOGRAPHIC DISTRIBUTION

Ammonites of the family Binneyitidae are known in the United States from Montana, Wyoming, South Dakota, Utah, Colorado, Kansas, and Texas (Text-fig. 1). Outside the United States the family is known only from Canada (Stelck & Wall, 1954, p. 14; Warren & Stelck, 1958, p. 45, pl. 7, fig. 4), Alaska (Gryc, 1951), and Turkestan (Arkhangel'skii, 1916, p. 55, pl. 8, figs. 2,3; text-fig. 20).

In the United States the published record of the family is small. *Binneyites* has been recorded only in the original paper of Reeside (1927, p. 5, pl. 3, figs. 1–10) and in lists of fossils by Cobban (1952, p. 758) and Yenne & Pipiringos (1954). These occurrences are all from the Cody shale of western Wyoming (Text-fig. 1, locs. 21097, USNM 73268, and YPM).

Borissiakoceras was first reported in the United States by Adkins (1933, p. 433) who recorded it as *Borissiakoceras* n. sp. from the Eagle Ford shale of Tarrant and Dallas Counties, Texas (Text-fig. 1, about same as loc. 11740). Two years later Morrow (1935) figured the first specimens from the United States, his new species *B. reesidei* and *B. aplatum* from the Graneros and Carlile shales of Kansas (Text-fig. 1, KU). Dane, Pierce & Reeside (1937, p. 210) recorded the genus farther west in southeastern Colorado (loc. 1323). The genus was not recorded again until 1951 when it was noted in the Carlile shale of western South Dakota (Cobban, 1951, p. 2188, loc. 21182) and in the Eagle Ford shale of east-central Texas (Adkins & Lozo, 1951, p. 123,132,144). Stephenson (1952, p. 198, pl. 45, figs. 5,6) figured from the Woodbine formation of Denton County, Texas, a small ammonite which he called *Euhoplites?* sp. Later (1955, p. 64,65) he referred it to *Borissiakoceras* and also described a new species *B. orbiculatum* from the basal part of the Eagle Ford shale of Tarrant County, Texas (loc. 11740). In the same year Hose (1955, p. 98,100) recorded *B. reesidei* Morrow and *B.* sp. from the Frontier formation and Cody shale of the west flank of the Powder River Basin of Wyoming (locs. 22804, 22811, 22815).

STRATIGRAPHIC DISTRIBUTION

Ammonites of the family Binneyitidae have been recorded from rocks as old as the Cenomanian (Morrow, 1935; Stephenson, 1952, 1955) and as young as the late Coniacian (Reeside, 1927). The collections studied by the writer extend the upper range of the family into the early Santonian. The stratigraphic positions of the American members of the Binneyitidae are shown in Table 1.

The oldest unquestioned Cenomanian megafossil zone in the Western Interior region is the level of the Thatcher limestone member of the Graneros shale of southeastern Colorado. The Thatcher limestone member and equivalent rocks contain, in addition to the new species *Borissiakoceras compressum* and *Johnsonites sulcatus*, an acanthoceratid ammonite fauna that is in need of study. *Calycoceras* sp. was suggested as a zonal index fossil by Cobban & Reeside (1952, p. 1017), but inasmuch as this genus is now known in the western interior from rocks as young as the early Turonian, the writer proposes using something more definite, such as *Borissiakoceras compressum*, as a guide fossil for this early zone.

Borissiakoceras reesidei Morrow occurs with *Acanthoceras? amphibolum* Morrow in Kansas (Morrow, 1935, p. 473) and Wyoming (Hose, 1955, p. 100).

Borissiakoceras orbiculatum Stephenson is associated with *Acanthoceras? wyomingense* (Reagan) at loc. 22871 on the north flank of the Black Hills uplift in southeastern Montana. *Acanthoceras? wyomingense* is the index fossil referred to as *Acanthoceras?* sp. A by Cobban & Reeside (1952, p. 1017). An examination of a plaster cast of the holotype (Stanford Univ. Paleo. Type Coll. No. 119) of *Metoicoceras wyomingense* Reagan (1924,

TEXT-FIG. 1—Localities of collections of Binneyitidae referred to in the text.

TABLE 1—POSITION OF THE BINNEYITIDAE IN RELATION TO SOME OF THE STAGES OF THE UPPER CRETACEOUS AND TO THE MARINE MEGAFOSSIL ZONES OF THE WESTERN INTERIOR REGION

Stages	Zone fossils	Binneyitidae
Santonian (lower)	*Clioscaphites vermiformis*	*Binneyites rugosus*
Coniacian	*Scaphites depressus* *Scaphites ventricosus* *Inoceramus deformis*	*Binneyites parkensis* *Binneyites nodosus*
Turonian	*Scaphites corvensis* *Scaphites nigricollensis* *Prionocyclus wyomingensis* *Scaphites warreni* *Collignoniceras hyatti* *Collignoniceras woollgari* *Inoceramus labiatus* *Sciponoceras gracile*	 *Binneyites aplatus* *Binneyites carlilensis* *Borissiakoceras* sp. *Borissiakoceras* cf. *orbiculatum*
Cenomanian	*Dunveganoceras albertense* *Dunveganoceras conditum* *Dunveganoceras pondi* *Acanthoceras? wyomingense* *Acanthoceras? amphibolum* *Borissiakoceras compressum*	? ? ? *Borissiakoceras orbiculatum* *Borissiakoceras reesidei* *B. compressum*, *Johnsonites sulcatus*

p. 181, pl. 19, figs. 1,2) reveals that this species is the same as the form referred to as *Acanthoceras?* sp. A, and that an assignment to *Acanthoceras?* is better than to *Metoicoceras*.

Members of the Binneyitidae are not known with certainty in the late Cenomanian zones of *Dunveganoceras pondi*, *D. conditum*, and *D. albertense*. Impressions of small ammonites in the Benton shale near Boulder, Colorado, (locs. D1807, D2323) may be *Borissiakoceras*, and, if so, they would show the presence of that genus in rocks equivalent to the Lincoln limestone member and Hartland shale member of the Greenhorn limestone of Kansas and eastern Colorado.

Borissiakoceras sp. is present in the early Turonian zone of *Sciponoceras gracile* (Shumard) in Wyoming (Hose, 1955, p. 98) and Texas (Adkins, 1933, p. 433). The genus is known also from the younger zone of *Inoceramus labiatus* (Schlotheim) in Wyoming (Hose, 1955, p. 98).

The oldest *Binneyites* is the new species *B. carlilensis* from the Turonian zone of *Collignoniceras woollgari* (Mantell) in the Black Hills region. *Binneyites aplatus* (Morrow) came from the next higher zone of *Collignoniceras hyatti* (Stanton). The later Turonian zones of *Scaphites warreni* Meek & Hayden, *Prionocyclus wyomingensis* Meek, *Scapphites nigricollensis* Cobban, and *S. corvensis* Cobban, have not yielded *Binneyites*.

Binneyites nodosus, n. sp., occurs in northwestern Montana with such early Coniacian species as *Inoceramus deformis* Meek, *Scaphites preventricosus* Cobban, and *Baculites mariasensis* Cobban.

Binneyites has not been found in the zone of *Scaphites ventricosus* Meek & Hayden, but *B. parkensis* Reeside is known from the next higher zone of *Scaphites depressus* Reeside of late Coniacian age.

Binneyites rugosus, n. sp., the youngest known species of the Binneyitidae, occurs in northwestern Montana with *Inoceramus cordiformis* Sowerby and *Clioscaphites vermiformis* (Meek & Hayden) of early Santonian age.

EVOLUTION WITHIN THE BINNEYITIDAE

The oldest members of the Binneyitidae, *Borissiakoceras compressum*, n. sp., and *Johnsonites sulcatus*, n. gen. and sp., appear suddenly in the Cenomanian in the Western Interior region. Nothing is known of their ancestors, and nothing is known of the descendents, if any, of *Johnsonites*. *Borissiakoceras*, on the other hand, left a fairly good record and gave rise to *Binneyites* in the late Turonian.

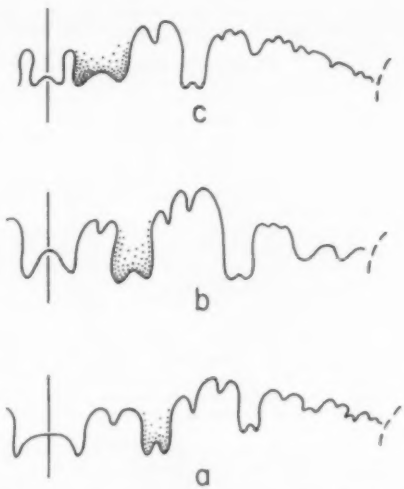
The species of *Borissiakoceras* reveal the following trends.

1. Decrease in size with decrease in geologic age. The oldest species, *B. compressum*, attains septate diameters of as much as 30 mm. The largest septate specimen of *B. reesidei* Morrow at hand is 17.7 mm. in diameter, and the largest *B. orbiculatum* Stephenson has a septate diameter of 10 or 11 mm.

2. Increase in the umbilical ratio with decrease in geologic age. Adults of *B. compressum* have ratios of 14–17 per cent whereas those of *B. reesidei* have ratios of 17–20 percent, and adults of *B. orbiculatum* have ratios of 20–24 percent.

3. Increase in ventrolateral noding with decrease in geologic age. Of the largest single lots at hand about 8 percent of *B. compressum* have nodes, whereas 38 percent of *B. orbiculatum* possess nodes.

Specimens of *Binneyites* are too few for making many evolutionary observations. Some sort of increase in size of the adult and decrease in size of the umbilicus from that of *Borissiakoceras* is probable. The few sutures examined reveal a narrowing of the ventral lobe and first lateral saddle and widening of the first lateral lobe with decrease in geologic age (Text-fig. 2). Descendents of *Binneyites* are unknown.



TEXT-FIG. 2—Generalized sutures of *a*, *Borissiakoceras compressum* Cobban, n. sp., *b*, *Binneyites carlilensis* Cobban, n. sp., and *c*, *B. parkensis* Reeside, showing that with decrease in geologic age the ventral lobe and first lateral saddle narrow and the first lateral lobe (stippled) widens.

COLLECTING LOCALITIES

The following localities are those referred to in the text that bear U. S. Geological Survey Mesozoic numbers.

U.S.G.S. Mesozoic locality 528.—Bluff along north side of Rock Creek about 7 miles north-northeast of Wilcox, Albany County, Wyoming. From a limestone concretion in lower part of Frontier formation.

U.S.G.S. Mesozoic locality 1323.—Near center of T. 22 S., R. 67 W., Pueblo County, Colorado. Graneros shale.

U.S.G.S. Mesozoic locality 12649.—Nineteen miles west-southwest of Alzada, in the SE¼ sec. 4, T. 57 N., R. 66 W., Crook County, Wyoming. From limestone concretions 35 feet above the "gray-red" bentonite bed in the upper part of the Belle Fourche shale.

U.S.G.S. Mesozoic locality 11740.—Walnut Creek, 4.75 miles east-northeast of Mansfield, Tarrant County, Texas. From the basal beds of the Eagle Ford shale.

U.S.G.S. Mesozoic locality 19501.—Timber Creek about 2.25 miles south-southwest of Lewisville, Denton County, Texas. Lewisville member of Woodbine formation.

U.S.G.S. Mesozoic locality 21097.—South-east bank of Ray Lake, 10 miles northwest of Lander, in the SW¼NW¼NE¼ sec. 25, T. 1 S., R. 1 W., Fremont County, Wyoming. From limestone concretions 800 feet above the base of the Cody shale.

U.S.G.S. Mesozoic locality 21181.—Five miles north of Belle Fourche, in the NE¼NW¼NW¼ sec. 14 and NW¼NE¼NE¼ sec. 16, T. 9 N., R. 2 E., Butte County, South Dakota. From light gray limestone concretions 12 feet above the base of the Carlile shale.

U.S.G.S. Mesozoic locality 21182.—Five miles north of Belle Fourche, in the NE¼ sec. 15, T. 9 N., R. 2 E., Butte County, South Dakota. From ferruginous concretions 57 feet above the base of the Carlile shale.

U.S.G.S. Mesozoic locality 21364.—Nine miles west-northwest of Parkman, in the SW¼ sec. 17, T. 58 N., R. 88 W., Sheridan County, Wyoming. Base of Cody shale.

U.S.G.S. Mesozoic locality 21422.—North bank of Marias River, 5.5 miles south of Shelby, in the NE¼ sec. 20 T. 31 N., R. 2 W., Toole County, Montana. From limestone concretions in the Marias River shale 514–525 feet below the top of the Kevin member.

U.S.G.S. Mesozoic locality 21425.—East bank of Marias River, 11 miles southwest of Shelby, in the W½NE¼SE¼ sec. 14, T. 31 N., R. 4 W., Toole County, Montana. From lime-

stone concretions in the Marias River shale 234–252 feet below the top of the Kevin member.

U.S.G.S. Mesozoic locality 21427.—Ashley Creek, 3 miles west of Jensen, in sec. 24, T. 5 S., R. 22 E., Uintah County, Utah. About 800 feet above the base of the Mancos shale.

U.S.G.S. Mesozoic locality 21591.—Top of small hill in the NE¼ sec. 15, T. 57 N., R. 62 W., Crook County, Wyoming. From light gray limestone concretions near the base of the Carlile shale.

U.S.G.S. Mesozoic locality 21792.—About 1.8 miles southwest of Newcastle, in the NW¼ sec. 31, T. 45 N., R. 61 W., Weston County, Wyoming. From light gray limestone concretions 62–70 feet above the base of the Carlile shale.

U.S.G.S. Mesozoic locality 21794.—Northeast side of Five Mile Creek valley, in the W½ sec. 14, T. 9 S., R. 60 E., Carter County, Montana. From light gray limestone concretions 18 feet below the top of the Greenhorn formation.

U.S.G.S. Mesozoic locality 22804.—One mile south of Muddy Creek, in the center of sec. 1, T. 48 N., R. 83 W., Johnson County, Wyoming. From limestone concretions 125 feet below the top of the Frontier formation.

U.S.G.S. Mesozoic locality 22811.—E½ sec. 13, T. 49 N., R. 83 W., Johnson County, Wyoming. About 190 feet above the base of the Cody shale.

U.S.G.S. Mesozoic locality 22815.—Two miles south of Dry Muddy Creek in the SE¼NE¼SW¼ sec. 12, T. 48 N., R. 83 W., Johnson County, Wyoming. From limestone concretions about 180 feet above the base of the Cody shale.

U.S.G.S. Mesozoic locality 22871.—Six miles northwest of Alzada, in the SE¼ sec. 6, T. 9 S., R. 59 E., Carter County, Montana. From a limestone concretion in the upper part of the Belle Fourche shale.

U.S.G.S. Mesozoic locality 22883.—About 19 miles southwest of Pueblo, near center of T. 22 S., R. 67 W., Pueblo County, Colorado. From Thatcher limestone member of the Graneros shale.

U.S.G.S. Mesozoic locality 22887.—North of Arkansas River, 6 miles west of Pueblo, in west half of sec. 30, T. 20 S., R. 65 W., Pueblo County, Colorado. From limestone concretions near the top of the Graneros shale.

U.S.G.S. Mesozoic locality 23062.—About 0.5 mile east of Five Mile Creek, in the SE¼ sec. 25, T. 9 S., R. 60 E., Carter County, Montana. From limestone concretions in the upper part of the Greenhorn formation.

U.S.G.S. Mesozoic locality 23460.—About 3 miles southwest of Kaycee, in SW¼ sec. 25, T. 43 N., R. 82 W., Johnson County, Wyoming. From silty concretions just above an 8-foot bentonite bed about 90 feet below the lowest sandstone member of the Frontier formation.

U.S.G.S. Mesozoic locality 23462.—About 3.5 miles southwest of Kaycee, in the NW¼ sec. 26, T. 43 N., R. 82 W., Johnson County, Wyoming. From a calcareous sandstone concretion just below an 8-foot bentonite bed about 90 feet below the lowest sandstone member of the Frontier formation.

U.S.G.S. Mesozoic locality 23466.—Between Belle Fourche River and U. S. Highway 212,

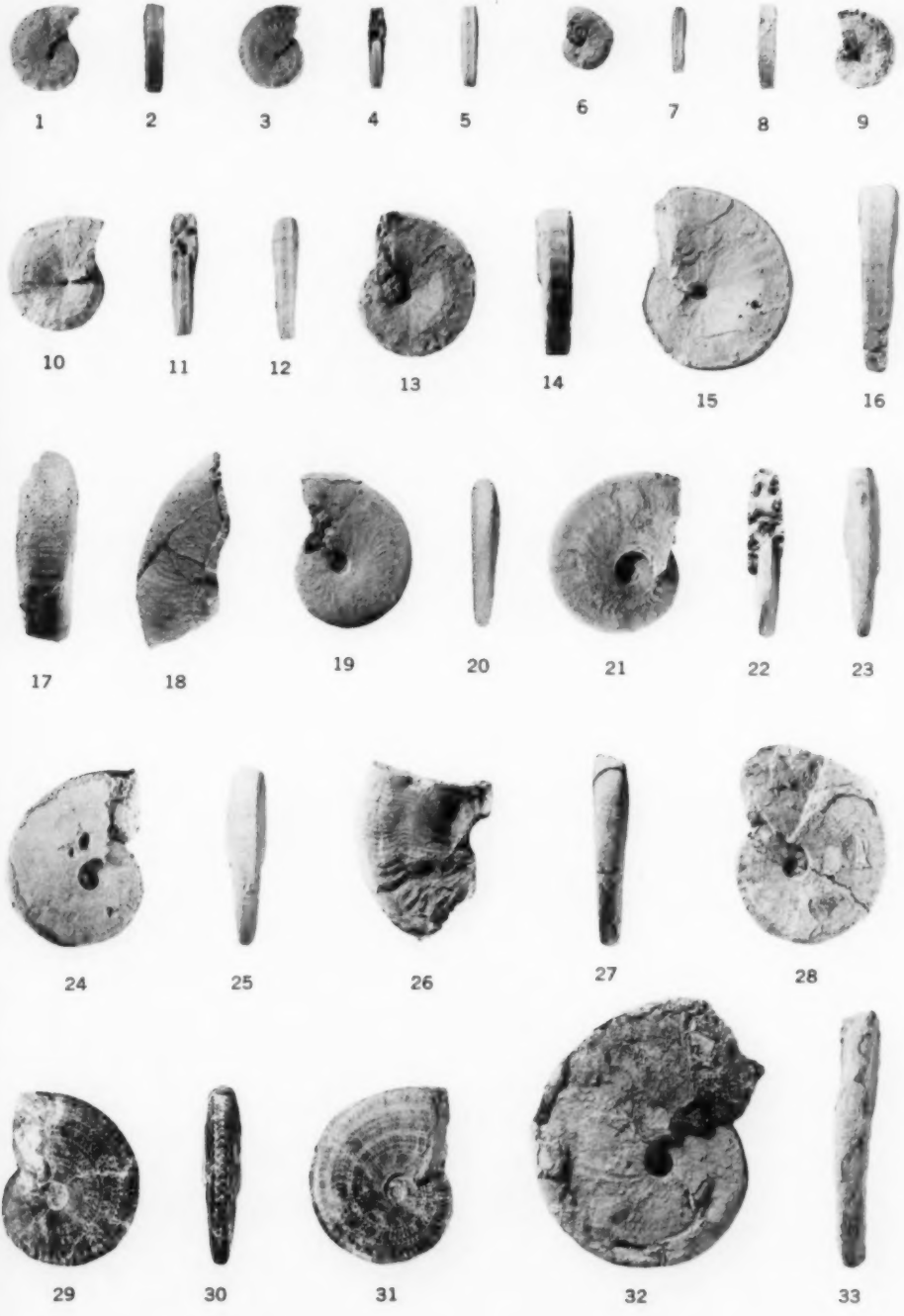
---

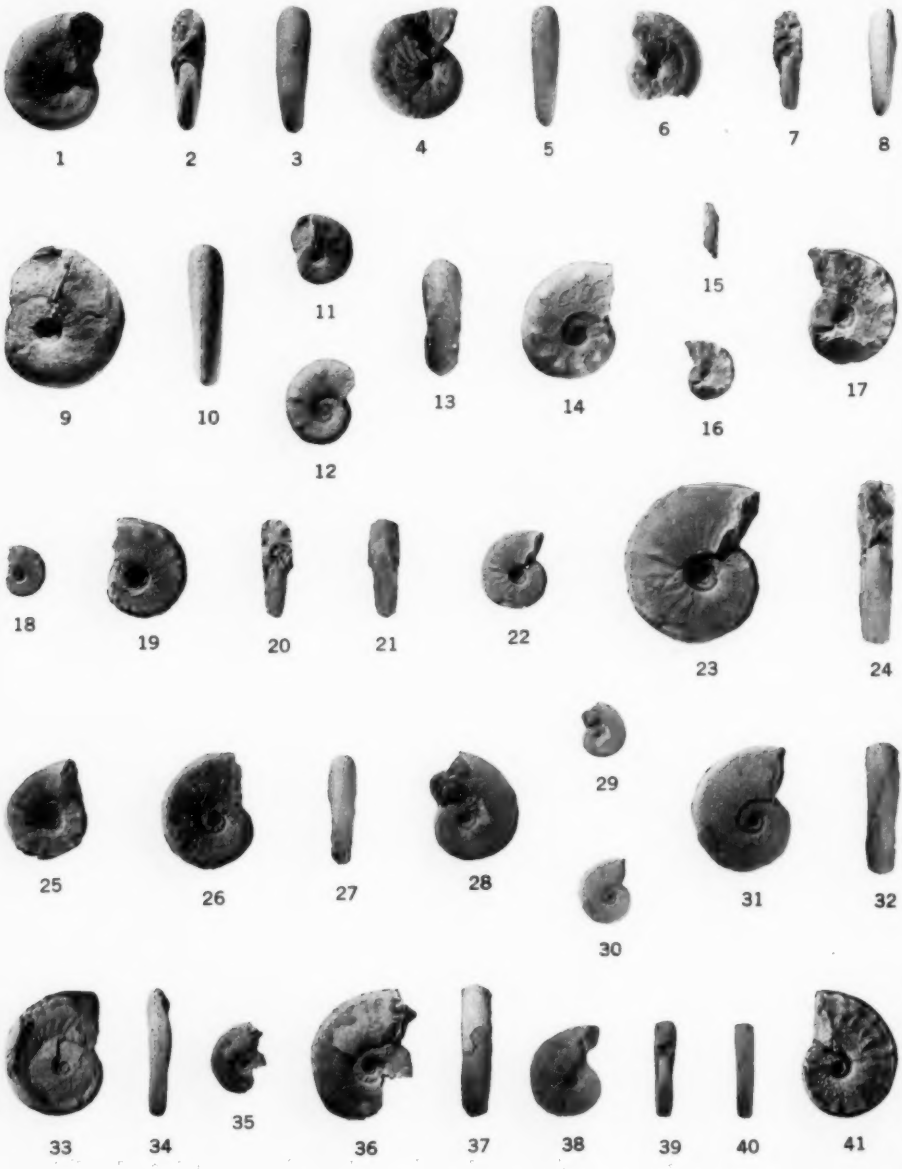
EXPLANATION OF PLATE 87

Figures 1–5 from loc. 528; all others from loc. 23462.

FIGS. *1–18*—*Johnsonites sulcatus* Cobban, n. sp. *1,2*, Side and rear views of the noded variant (USNM 130819a), ×2; *3–5*, side, front, and rear views of the internal mold of a septate specimen (USNM 130819b), ×1; *6,7*, side and rear views of a smooth sulcate juvenile (USNM 130817a), ×1; *8,9*, rear and side views of the internal mold of a flat-ventered septate specimen (USNM 130817b), ×1; *10–12*, side, front, and rear views of the holotype (USNM 130816), ×1; *13,14*, side and rear views of a stout septate paratype (USNM 130817c) that has an undulated venter, ×1; *15,16*, side and rear views of the largest septate specimen (USNM 130817d), ×1; *17,18*, rear and side views of a fragment of a body chamber (USNM 130817e), an internal mold that shows the form of the growth lines and part of the margin of the aperture, ×1.

19–33—*Borissiakoceras compressum* Cobban, n. sp. *19,20*, Side and rear views of a septate specimen (USNM 130822a) showing raised falcoid growth lines, ×1; *21–23*, side, front, and rear views of an internal mold (USNM 130822b) showing faint falcoid ribbing, ×1; *24,25*, side and rear views of the holotype (USNM 130821), ×1; *26*, side view of part of a body chamber (USNM 130822c) that has falcoid ribs and raised growth lines, ×1; *27,28*, rear and side views of an adult septate whorl with a part of the body chamber attached (USNM 130822d), ×1; *29,30*, side and rear views of an uncoated paratype (USNM 130822e) that has 50 chambers in the last complete septate whorl, ×1; *31*, side view of a paratype (USNM 130822f) that has 70 chambers in the last complete whorl, ×1; *32,33*, side and rear views of a somewhat crushed but nearly complete adult (USNM 130822g), ×1.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41

in the E½ sec. 22 T. 57 N., R. 62 W., Crook County, Wyoming. From the upper part of the Belle Fourche shale.

U.S.G.S. Mesozoic locality D1807.—Road cut in the NE¼SE¼SW¼ sec. 36, T. 1 N., R. 71 W., Boulder County, Colorado. Benton shale, from calcareous shale equivalent to Hartland shale member of Greenhorn limestone.

U.S.G.S. Mesozoic locality D2323.—Near middle of SE¼ sec. 25, T. 2 N., R. 71 W., Boulder County, Colorado. Benton shale, from calcareous rocks equivalent to Lincoln limestone member of Greenhorn limestone.

SYSTEMATIC DESCRIPTIONS

Class CEPHALOPODA
Order AMMONOIDEA
Family BINNEYITIDAE Reeside, 1927
Genus JOHNSONITES Cobban, n. gen.

Type species.—*Johnsonites sulcatus* Cobban, n. sp.

Diagnosis.—*Johnsonites* is a small more or less flat-sided very involute ammonite that has a flat to slightly convex or slightly concave venter. The shell is smooth or nearly smooth. The suture pattern is simple for an ammonite. It has a narrow ventral lobe with deep ventral saddle. The first lateral saddle is broad and bifid; the first lateral lobe is narrow and about the size of the ventral lobe; the second lateral saddle is higher and much smaller than the first, and the second lateral lobe is considerably smaller than the first lateral lobe. The auxiliaries are numerous and simple.

JOHNSONITES SULCATUS Cobban, n. sp.
Pl. 87, figs. 1–18; text-figs. 3a–g

Diagnosis.—This species is characterized by the early flattening of the venter which rapidly becomes depressed to form a low, broad sulcus. This sulcated venter persists during the later growth of the conch. Most specimens are smooth at all growth stages; a small minority has an early noded stage.

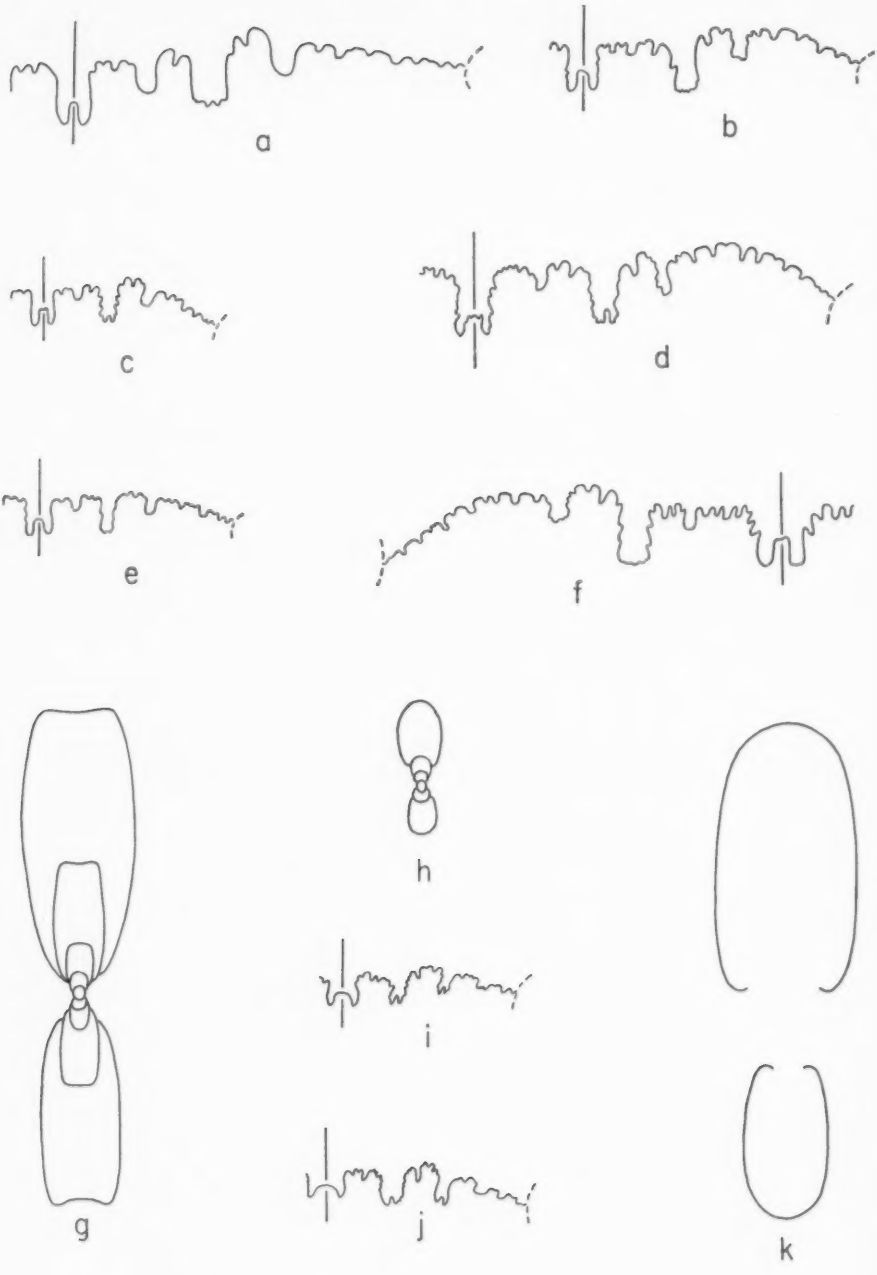
Material.—The types came from two lots each of which was collected from a single concretion. The holotype (USNM 130816) is from a collection of twelve individuals found in a very fine-grained calcareous sandstone concretion about 100 feet below the lowest conspicuous sandstone member of the Frontier formation at U.S.G.S. Mesozoic

---

EXPLANATION OF PLATE 88

FIGS. *1–14*—*Borissiakoceras reesidei* Morrow. *1–3*, Side, front, and rear views of the holotype (Kansas Univ. 11276), ×1; *4,5*, side and rear views of a septate internal mold (USNM 130825a) with part of the crushed body chamber attached, from loc. 21364, ×1; *6–8*, side, front and rear views of a specimen (USNM 130825b) that retains most of the shell material, from loc. 21364, ×1; *9,10*, side and rear views of a septate specimen (USNM 130825d) showing the falcoid growth lines, from loc. 21364, ×2; *11*, side view of the same specimen, ×1; *12*, side view of a juvenile (USNM 130825d) with ventrolateral nodes, from loc. 21364, ×4; *13,14*, rear and side views of a juvenile (USNM 130825e) with nodes, from loc. 21364, ×4.

15–41—*Borissiakoceras orbiculatum* Stephenson. *15,16*, Rear and side views of a small strongly noded specimen (USNM 130827a), from loc. 22871, ×1; *17*, side view of same specimen, ×2; *18*, side view of a stout septate internal mold (USNM 130827b) retaining a small part of the shell material, from loc. 22871, ×1; *19–21*, side, front, and rear views of the same specimen, ×2; *22*, side view of a small adult (USNM 130827c) that shows the margin of the aperture, from loc. 22871, ×1; *23,24*, side and front views of the same specimen, ×2; *25*, side view of a small evolute individual (USNM 130827d) with complete body chamber that shows loss of nodes toward the aperture, from loc. 22871, ×2; *26*, side view of a small moderately evolute specimen (USNM 130827e) with nearly complete body chamber, from loc. 22871, ×3; *27,28*, rear and side views of the smooth variant (USNM 130827f) with nearly complete body chamber, from loc. 22871, ×2; *29*, side view of same specimen, ×1; *30*, side view of the smooth variant (USNM 130827g) with most of the shell material, from loc. 22871, ×2; *31,32*, side and rear views of the same specimen, ×4; *33,34*, side and rear views of a somewhat crushed adult (USNM 130827h) of the smooth variant showing flank ribbing, from loc. 22871, ×1; *35*, side view of a small evolute adult (USNM 130829) with complete body chamber, from loc. 12649, ×1; *36,37*, side and rear views of the same specimen, ×2; *38–40*, side, front, and rear views of an adult (USNM 108834), an internal mold from loc. 12649, ×1; *41*, side view, ×1, of the holotype (USNM 108832), after Stephenson.


a
b
c
d
e
f
g
h
i
j
k

locality 23462 near Kaycee in Johnson County, Wyoming. Most of these specimens are adults.

The second lot consists of numerous specimens from a gray silty limestone concretion from the Frontier formation at U.S.G.S. Mesozoic locality 528 near Wilcox in Albany County, Wyoming. The bulk of the specimens are juveniles less than 3 mm. in diameter. About 206 specimens are larger than 3 mm. in diameter, but individuals greater than 13 mm. are few and too crushed for suitable measurements. The number of specimens in the rock is remarkable; one slab from the concretion shows on a surface of about 40 square inches more than 600 of these ammonites from 2 to 20 mm. in diameter and probably as many more with diameters less than 2 mm. This collection, made by Alpheus Hyatt and I. C. Russell in 1888, was said to have come from "Bluff one mile northeast of Wilcox, Wyoming." The present Wilcox is located on the Lincoln highway (U.S. 30) and Union Pacific Railway near the center of sec. 18, T. 21. N., R. 76 W. (Wilcox quadrangle). The old Wilcox siding was located on a now abandoned railway grade about 7 miles to the north-northeast. According to the 1883 Department of Interior's General Land Office map of the Territory of Wyoming, Wilcox (Willcox on map) was in sec. 16, T. 22 N., R. 76 W. Rock Creek flows about a mile north and east of old Wilcox siding, and bluffs in the Frontier formation are present along the north side of the creek.

Description.—Of the 206 specimens from loc. 528 that are 3 mm. or more in diameter, 200 are entirely smooth. The other six have low ventrolateral nodes on part of the early whorls. The smooth specimens will be referred to as the typical form, and the few ornate specimens will be considered as a noded variant.

At a diameter of 0.5 mm. the whorl section is considerably broader than high. The height of the whorls increases rapidly, and by a diameter of 1.3 mm. the height and width are equal. At all greater diameters the height exceeds the width (Text-fig. 3g). The flanks are rounded at diameters less than 2 mm. They flatten at a diameter between 2 and 3 mm. and tend to become parallel up to a diameter of about 10 mm. At larger diameters the flanks round slightly with the greatest width about in the middle. On the typical form of the species the venter flattens at a diameter between 3.4 and 4.2 mm., and a distinct ventrolateral shoulder develops. The venter becomes slightly concave between diameters of 6 and 7 mm. and remains so at all greater sizes.

The umbilicus is very small with abrupt sides. Measurements of the umbilical ratios of 52 uncrushed specimens from loc. 528 are summarized in the following table. These specimens, chiefly juveniles, reveal a very slight decrease in the umbilical ratio as the shell enlarges. That this tendency continues in the adults is suggested by the 7 specimens

TABLE 2—UMBILICAL RATIOS OF *JOHNSONITES SULCATUS*

Diameter (mm.)	Umbilical ratios (%)	Number of specimens
2– 3.9	6.6	6
4– 5.9	6.2	17
6– 7.9	5.7	15
8– 9.9	6.1	8
10–11.9	6.1	4
12–13.9	5.5	2

TEXT-FIG. *3—a–g—Johnsonites sulcatus* Cobban, n. sp. *a*, suture, ×4, of a paratype, USNM 130817c, at diameter of 22 mm. (Pl. 87, figs. 13,14); *b*, suture, ×4, of the holotype, USNM 130816, at diameter of 16 mm. (Pl. 87, figs. 10–12); *c*, suture, ×4, of a paratype, USNM 130819b, at diameter of 10.2 mm. (Pl. 87, figs. 3–5); *d*, suture, ×4, of a paratype, USNM 130817f, from loc. 23462; *e*, suture, ×4, of a paratype, USNM 130817b, at diameter of 9.5 mm. (Pl. 87, figs. 8,9); *f*, suture, ×4, of a paratype, USNM 130817d, at diameter of 24 mm. (Pl. 87, figs. 15,16); *g*, cross section, ×4, of a paratype, USNM 130817g, from loc. 23462. *h-k—Borissiakoceras reesidei* Morrow, *h*, cross section, ×4, of a juvenile, USNM 130825f, from loc. 21364; *i*, suture, ×4, of a specimen, USNM 130825g, from loc. 21364; *j*, suture, ×4, of a specimen, USNM 130825a, at diameter of 13 mm. (Pl. 88, figs. 4,5); *k*, cross section, ×4, of the holotype, Kansas Univ. 11276.

from loc. 23462 suitable for measurement. Their dimensions and umbilical ratios are as follows.

TABLE 3—DIMENSIONS AND UMBILICAL RATIOS OF 7 SPECIMENS OF *JOHNSONITES SULCATUS*

USNM Specimen	Diameter (mm.)	Width (mm.)	Umbilicus (mm. and %)
130817a	9.8	2.5	0.7 (7.1)
130817b	13.5	3.8	0.8 (5.9)
130818b	18.3	6.0	0.9 (4.9)
130816	19.3	4.5	1.0 (5.2)
130817c	23.4	5.9	1.1 (4.7)
130818a	25.9	6.4	1.2 (4.6)
130817d	26.0	6.0	1.7 (6.5)

Only one specimen (Pl. 87, figs. 17,18) preserves part of the aperture. It seems to follow the shape of the falcoid growth lines of the flanks.

The typical form of the species attains a large size for the family Binneyitidae. One paratype, USNM 130817d, is septate at a diameter of 29 mm. (Pl. 87, figs. 15,16). Large adults probably attained diameters of as much as 40 mm.

The typical form ordinarily has a smooth shell. Rarely a specimen shows faint falcoid flank ribbing (Pl. 87, fig. 15) or scarcely discernible broad undulations that run straight across the venter (Pl. 87, fig. 14). The growth lines also trend straight across the venter (Pl. 87, fig. 17).

The suture pattern is distinctive. The ventral lobe is narrow and divided by a long and narrow ventral saddle. The first lateral saddle is very broad and symmetrically bifid with the two parts denticulate. The first lateral lobe is slightly smaller than the ventral lobe. It tends to be bifid and frilled. The second lateral saddle is bifid and higher than the first lateral saddle but only about half as wide. The second lateral lobe is about half as long and wide as the first and simple to slightly denticulate. The auxiliaries either run straight toward the umbilicus (Text-figs. 3a,c) or are curved backward (Text-figs. 3d,f).

The noded variant (Pl. 87, figs. 1,2) is represented only by 6 juveniles from loc. 528. The early whorls are like those of the typical form except the venter flattens at a smaller diameter (3.0–3.4 mm.). Low clavi, spaced 5–8 per half whorl, first appear along the well defined ventrolateral shoulder at diameters between 3.2–3.5 mm. and persist for less than a complete whorl.

TABLE 4—DIMENSIONS, UMBILICAL RATIOS, AND DIAMETERS AT WHICH NODES APPEAR ON *JOHNSONITES SULCATUS* FROM LOCALITY 528

USNM Specimen	Diameter (mm.)	Width (mm.)	Umbilicus (mm. & %)	Diameter at which nodes appear
130820a	4.5	1.1	0.3 (6.7)	3.4
130820b	4.7	1.2	0.3 (6.4)	3.5
130820c	4.9	1.2	0.3 (6.1)	3.2
130820d	5.2	1.2	0.4 (7.7)	3.2
130820e	6.2	1.6	0.5 (8.1)	3.5
130819a	6.4		0.5 (7.8)	3.5

The holotype of the species (Pl. 87, figs. 10–12; Text-fig. 3b) is a septate internal mold 20.2 mm. in diameter and 4.8 mm. wide.

Remarks.—Stephenson (1952, p. 198, pl. 45, figs. 5,6) figured as *Euhoplites?* sp., a fragment of a small ammonite from the Lewisville member of the Woodbine formation at loc. 19501 in Denton County, Texas. This specimen, which consists of a portion of the venter and outer part of the flank of a body chamber, has "nearly flat flanks, diverging only slightly inward from the relatively broad venter, which is rounded on the edges and is transversed centrally by a rather broad, shallow depression. The growth lines are strongly sigmoidal on the flanks and swing well forward on the venter." Stephenson (1955, p. 64) later considered this specimen as *Borissiakoceras*. Stephenson's specimen seems to differ from *Johnsonites sulcatus* only by the forwardly arched growth lines on the venter.

Occurrence.—Aside from its presence in the Frontier formation at locs. 528 and 23462 in Wyoming, *Johnsonites sulcatus* is known in the Western Interior region only from southern Colorado. Erle G. Kauffman of the University of Michigan found the species in argillaceous limestone concretions 150 feet above the base of the Graneros shale in sec. 12, T. 25 S., R. 70 W. of the Huerfano Park area of Colorado (personal

communication). A questionable specimen was found by G. K. Gilbert in rocks now assigned to the Thatcher limestone member of the Graneros shale at loc. 22883 northeast of Huerfano Park in T. 23 S., R. 67 W.

Types.—Holotype, USNM 130816; figured paratypes, USNM 130817a–g, 130819a, 130819b; unfigured paratypes, USNM 130818a, 130818b, 130820a–ddd.

Genus Borissiakoceras Arkhangel'skii 1916

Type species.—*Borissiakoceras mirable* Arkhangel'skii.

Diagnosis.—This genus is characterized by the small size of the conchs which are ordinarily compressed and moderately evolute to somewhat involute. The venter is rounded to flat. Most shells are smooth but a few have raised falcoid growth lines or faint closely spaced falcoid ribs. Nodes, when present, are on the ventrolateral shoulder. The suture has a broad ventral lobe indented by a broad shallow ventral saddle. The first lateral saddle is bifid and as wide as the ventral lobe. The first lateral lobe is narrow, bifid, and about half as wide as the ventral lobe. The second lateral saddle is trifid and higher and broader than the first. The second lateral lobe is about half as large as the first and tends to be bifid. The auxiliaries, which are small and shallow, may be divided into bifid lobes and saddles.

Borissiakoceras compressum Cobban, n. sp.
Pl. 87, figs. 19–33; pl. 89, figs. 1–9; text-figs. 4a-k

Diagnosis.—This species, which is large for the genus, has a very narrow cross section, nearly flat flanks, broadly rounded venter, and somewhat narrow umbilicus. Almost all specimens are entirely smooth. The suture is complex for the genus.

Material.—The holotype and most of the paratypes are from a very fine-grained calcareous sandstone concretion about 100 feet below the lowest sandstone member of the Frontier formation at loc. 23462 near Kaycee, Wyoming (same concretion that contained the holotype of *Johnsonites sulcatus*). Sixty-five specimens, from 8.7–44.7 mm. in diameter, suitable for measurement are from this concretion. About 100 additional specimens are from other concretions at this level in the Kaycee area. Eight uncrushed specimens, 3.8–16.5 mm. in diameter, are from the limestone concretion at loc. 528 near Wilcox, Wyoming. A few other specimens, largely crushed or distorted, are at hand from localities in Colorado.

Description.—The typical form of the species is smooth at all growth stages. Sixty of the 65 uncrushed specimens from the sandstone concretion at loc. 23462 are this form. The remaining 5 represent a noded variant. Of the 8 uncrushed specimens from the limestone concretion at loc. 528, one is noded.

The whorls are depressed at a diameter of 0.5 mm. but become as high as they are wide by a diameter of 1 mm. At greater diameters the height exceeds the width. The flanks are rounded at first but become flattened and parallel-sided at a diameter of 2 mm. They remain this way until the shell attains a diameter of 6 or 7 mm. The venter then narrows although remaining broadly rounded; the flanks remain flat but convergent; and the whorls attain their greatest width near the umbilical shoulder. The resulting somewhat tabulate cross section of the whorls persists until the shell attains a diameter of about 30 mm. Body chambers of shells larger than this are more or less crushed, but they suggest a return to a rectangular cross section with nearly flat venter and sharply rounded ventrolateral shoulder.

The umbilicus is moderately narrow and sharply defined. The umbilical shoulder is almost angular. An umbilical ratio of 13–17 percent is normal for this species. Up to a diameter of 16 mm. the umbilical ratio seems to decrease slightly from about 14 to 13 percent; it then increases a little as the shell enlarges as shown by the measurements in Table 5 of 59 specimens from the sandstone concretion at loc. 23462.

None of the specimens at hand has a complete adult aperture. The shape of the aperture seems to be that of the falcoid growth lines visible on the flanks of some individuals.

Most specimens are entirely smooth. A few show raised growth lines, and rarely an

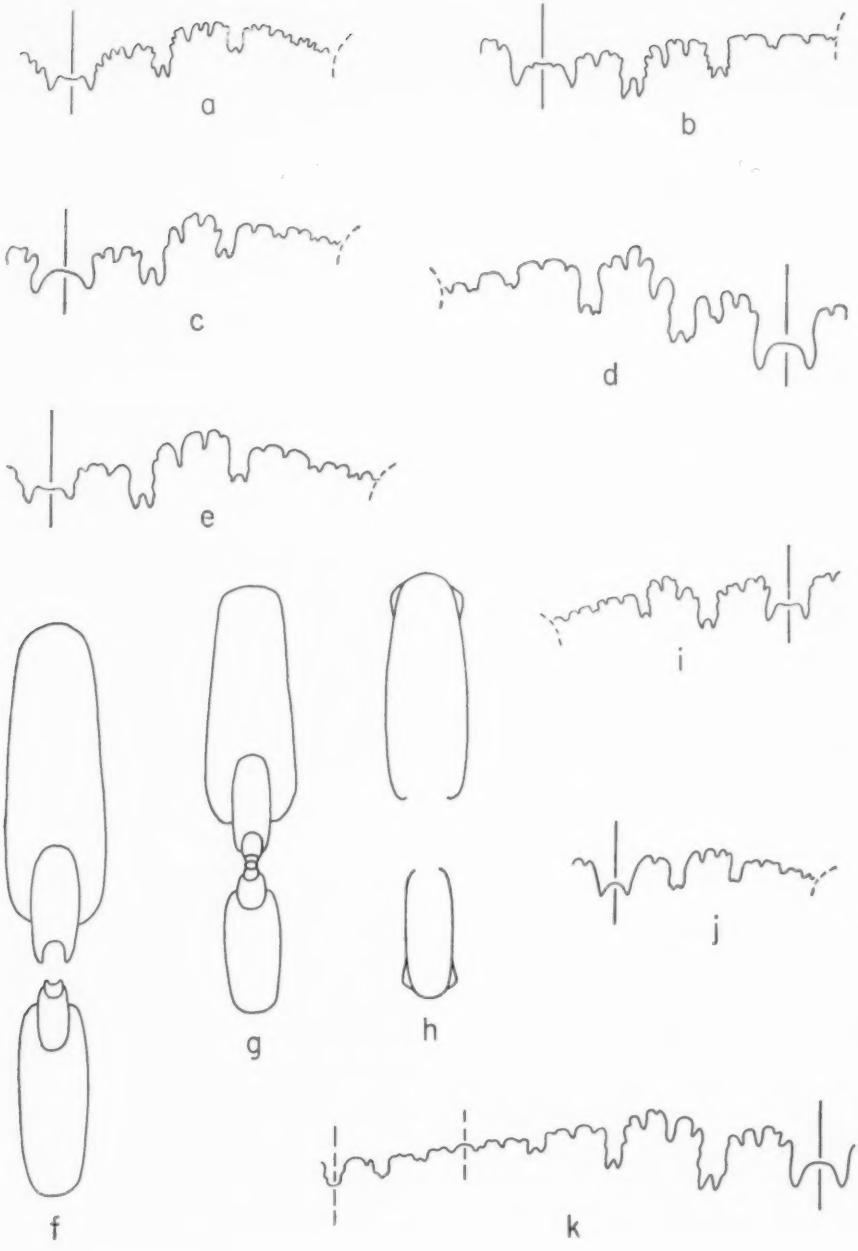

a
b
c
d
e
i
j
g
h
f
k

TABLE 5—UMBILICAL RATIOS OF *BORISSIAKOCERAS COMPRESSUM*

Diameter (mm.)	Umbilical ratios (%)	Number of specimens
8– 9.9	13.9	2
10–11.9	13.9	2
12–13.9	13.3	5
14–15.9	13.1	8
16–17.9	14.0	11
18–19.9	13.5	9
20–21.9	14.9	3
22–23.9	14.0	9
24–25.9	14.9	6
26–27.9	16.7	2
28–29.9	16.9	2

adult has faint closely spaced falcoid ribs (Pl. 87, figs. 21,26).

The noded variant has 5–7 rounded ventrolateral nodes per half whorl (Pl. 89, figs. 1–7). These appear at a diameter of about 5 mm. and disappear around 20 mm. Rarely, flank ribs are present (Pl. 89, fig. 5).

Borissiakoceras compressum is the largest known member of the genus. Specimens are septate up to diameters of 30 mm. The complete adult shell has a diameter of about 45 mm. (Pl. 87, figs. 32,33).

The sutures commonly show extreme crowding (Pl. 87, figs. 29–31) reminiscent of certain Triassic species (Smith, 1914, pl. 21, fig. 18; pl. 30, fig. 16). The ventral lobe is broad and indented by a shallow ventral saddle. The first lateral saddle, which is as broad as the ventral lobe, is bifid with the two halves further divided. The first lateral lobe is narrow, bifid, and about half as wide as the ventral lobe. The second lateral saddle is higher and broader than the first. It tends to be trifid with the deepest dividing lobule nearest the venter. The second lateral lobe is bifid and smaller than the first. The auxiliaries run straight to the umbilicus.

The holotype is a septate specimen 28.7 mm. in diameter and 5.8 mm. in width. The umbilicus is 5 mm. across with a ratio of 17.4 percent.

Remarks.—*Borissiakoceras compressum* differs from all described species of the genus by its large size, compressed form, and tabulate cross section of the early adult whorls. *Borissiakoceras reesidei* Morrow (1935, p. 463, pl. 49, figs. 7a,7b; pl. 50, fig. 5; text-fig. 8), from the upper part of the Graneros shale of Kansas, has an adult umbilical ratio (16 percent) comparable to that of *B. compressum* but the cross section is shaped differently and the early whorls are considerably more evolute.

Occurrence.—*Borissiakoceras compressum* is known from Wyoming and Colorado. In Wyoming it occurs below the level of the "Third Wall Creek" sandstone member of the Frontier formation at locs. 528, 23460, and 23462, and in the upper part of the Belle Fourche shale at loc. 23466. In Colorado it occurs at the level of the Thatcher limestone member of the Graneros shale at locs. 1323 and 22883 near Pueblo.

Types.—Holotype, USNM 130821; figured paratypes, USNM 130822a-o, 130824; unfigured paratypes, USNM 130823a-zz

BORISSIAKOCERAS REESIDEI Morrow
Pl. 88, figs. 1-14; text-figs. 3h-k

Borissiakoceras reesidei MORROW, 1935, p. 463, pl. 49, figs. 7a,7b; pl. 50, fig. 5; text-fig. 8.

Diagnosis.—This species, of average size for the genus, has moderately evolute early whorls and less evolute later whorls. The venter is well rounded and the flanks broadly rounded to nearly flat. Ventrolateral nodes, spaced 5 or 6 per half whorl,

←

TEXT-FIG. 4—*Borissiakoceras compressum* Cobban, n. sp. *a*, suture, ×4, of the noded variant, USNM 130822h, at diameter of 18 mm. (Pl. 89, figs. 3,4); *b*, suture, ×4, of the holotype, USNM 130821, at diameter of 21 mm. (Pl. 87, figs. 24,25); *c*, suture, ×4, of a paratype, USNM 130822k, at diameter of 17.8 mm., from loc. 23462; *d*, suture, ×4, of a paratype, USNM 130822l, at diameter of 22.5 mm., from loc. 23462; *e*, suture, ×4, of a paratype, USNM 130822d, at diameter of 19 mm. (Pl. 87, figs. 27,28); *f*, cross section, ×4, of a paratype, USNM 130822m, from loc. 23462; *g*, cross section, ×4, of a paratype, USNM 130822n, from loc. 23462; *h*, cross section, ×4, of the noded variant, USNM 130822i, at diameter of 16 mm. (Pl. 89, figs. 5–7); *i*, suture, ×4, at diameter of 15.8 mm. of the same specimen; *j*, suture, ×4, of the noded variant, USNM 130824, at diameter of 13.2 mm. (Pl. 89, figs. 1 2); *k*, complete suture, ×4, of a paratype, USNM 130822o, from loc. 23462.

are ordinarily present and may persist to a shell diameter of as much as 12 mm.

Material.—The species is best represented by a collection of 15 uncrushed specimens from the base of the Cody shale at loc. 21364 northwest of Parkman, Wyoming. Morrow's type lot from the Graneros shale of Kansas consisted of 3 specimens.

Description.—At the smallest diameter observed, 0.6 mm., the whorls are wider than high. At a diameter of 1 mm. the height and width are the same but at larger diameters the height exceeds the width. The venter is well rounded and merges evenly into the flanks. The flanks flatten somewhat at a diameter of about 2 mm. and diverge outward slightly. The cross section changes little with further growth other than to become taller in proportion to the width.

The umbilicus is wide on the early whorls with a ratio of 26–30 percent for shells less than 5 mm. in diameter (Pl. 88, figs. 12,14). As growth continues the shells become less evolute. The umbilical ratio averages 21 percent for the 4 shells at hand that have diameters between 5 and 10 mm. The ratio drops to an average of 19 percent for the 3 specimens between 10 and 15 mm. diameter. The holotype has an umbilical ratio of 15.8 percent at a diameter of 19 mm.

Ventrolateral nodes appear early at diameters between 2.3–2.9 mm. They are round, rather pointed, and spaced 5 or 6 per half whorl (Pl. 88, figs. 12,14). They apparently persist for only a short distance, inasmuch as the shells from loc. 21364 more than 5 mm. in diameter are smooth. The holotype, from Kansas, seems to be exceptional by maintaining nodes to a diameter of 11.8 mm. Node counts, dimensions, and umbilical ratios of the 15 specimens from loc. 21364 in Wyoming are given in the following table.

The species is about average size for the genus. The largest septate diameter observed is 17.7 mm. (Pl. 88, figs. 4,5). The complete adult was probably a little more than 20 mm. in diameter.

The suture illustrated by Morrow (1935, pl. 50, fig. 5) is from a juvenile and, accordingly, is not as complex as that of an adult. The larger specimens from loc. 21364 reveal a considerably denticulate pattern (Text-figs. 3i,j).

TABLE 6—DIMENSIONS, UMBILICAL RATIOS, AND NODES PER HALF WHORL OF *BORISSIAKOCERAS REESIDEI*

USNM Specimen	Diameter (mm.)	Width (mm.)	Umbilicus (mm. & %)	Nodes per half whorl
130826a	2.3	1.1	0.6 (26.1)	5
130825d	3.2	1.2	0.9 (28.1)	5
130826b	3.7	1.3	1.0 (27.0)	5
130826c	3.7	1.2	1.1 (30.0)	—
130826d	3.9	1.3	1.1 (28.2)	6
130825e	4.6	1.5	1.3 (28.3)	6
130826e	4.9	1.4	1.3 (26.5)	5
130826f	7.4	2.3	1.7 (23.0)	—
130825f	7.4	2.5	1.6 (21.6)	—
130826g	8.0	2.4	1.6 (20.0)	—
130826h	8.8	2.5	1.7 (19.3)	—
130825c	11.2	3.2	2.2 (19.6)	—
130826i	13.6	3.5	2.4 (17.6)	—
130825b	13.7	3.9	2.7 (19.7)	—
130825a	17.4	4.3	3.0 (17.2)	—

The holotype is an internal mold of most of an adult 19 mm. in diameter and 5.7 mm. in width. It is stouter than most of the specimens from the Wyoming locality.

Occurrence.—The holotype is from a limestone concretion in the upper part of the Graneros shale south of Wilson in Ellsworth County, Kansas. Elsewhere the species is known from the base of the Cody shale at loc. 21364 near Parkman on the east flank of the Bighorn Mountains in northern Wyoming; in the upper part of the Frontier formation along the east flank of the Bighorn Mountains but farther south at loc. 22804 (Hose, 1955, p. 100); and near the top of the Graneros shale at loc. 22887 near Pueblo, Colorado.

Types.—Holotype, Kansas Univ. 11276; plesiotypes, USNM 130825a-g; measured specimens, USNM 130826a-i.

BORISSIAKOCERAS ORBICULATUM Stephenson

Pl. 88, figs. 15-41; text-figs. 5a-f

Borissiakoceras orbiculatum STEPHENSON, 1955, p. 64, pl. 6, figs. 1–4.

Borissiakoceras sp., STEPHENSON, 1955, p. 64, pl. 6, fig. 5.

Diagnosis.—This is a small moderately evolute species that has flattened flanks and subangular ventrolateral shoulder with or without low clavi. The suture is simple for the genus.

Material.—Stephenson had only 3 speci-

mens, all from the basal beds of the Eagle Ford shale of Tarrant County, Texas. In addition to these he figured a specimen from the Belle Fourche shale on the northwest flank of the Black Hills uplift in northeastern Wyoming (loc. 12649). Stephenson noted the close resemblance of the Black Hills specimen with the Texas forms, but he regarded the former as a separate undescribed species because of the "less conspicuous development of the ventral nodes." The writer collected 60 specimens of *Borissiakoceras* from a limestone concretion in the upper part of the Belle Fourche shale at loc. 22871 on the north flank of the Black Hills in southeastern Montana. These reveal a range in variation that would include Stephenson's specimens from the Black Hills and Texas.

Description.—Of the 60 specimens from loc. 22871, 23 are noded and 37 are smooth. Inasmuch as the holotype from Texas is noded, the smooth specimens will be referred to as a smooth variant.

The noded specimens from loc. 22871 range in diameter from 1.2–12.5 mm. At a diameter of 1.2 mm. the whorls are of equal height and width, and the venter and flanks are well rounded. Between diameters of 1.5-2 mm. the height of the whorls becomes greater than the width, the flanks flatten, and a distinct ventrolateral shoulder develops. Nodes form along the ventrolateral shoulder at diameters between 2 and 3 mm. They are at first rounded and spaced 5 or 6 per half whorl, but later they become arcuate to clavate and more closely spaced (7–10 per half whorl). They commonly weaken at a diameter of 6 or 7 mm. and disappear on the body chamber (Pl. 88, fig. 25). The venter is well rounded on the septate whorls and broadly rounded on the adult body chamber. The ventrolateral shoulder, which early became subangular, remains sharply defined to the adult aperture. The whorl height continues to increase at a greater rate than the width which results in the adult whorls generally being twice as high as wide (Text-figs. 5d,e). The flanks are almost flat and parallel on the adult.

The 23 noded specimens from loc. 22871 have umbilical ratios of 20.8–33.8 percent. In general the umbilical ratio decreases as the shell diameter increases.

Aside from the lack of nodes, the smooth variant of *B. orbiculatum* differs from the noded form by being slightly less evolute and by having a more rounded ventrolateral shoulder. The umbilical ratios of the 37 specimens are shown in the following table.

TABLE 7—UMBILICAL RATIOS OF NODED FORM OF *BORISSIAKOCERAS ORBICULATUM*

Diameter (mm.)	Umbilical ratios (%)	Number of specimens
2 – 3.9	26.8	8
4 – 5.9	26.5	5
6 – 7.9	25.4	7
8 – 9.9	22.5	2
10 –11.9		0
12.5	24.0	1

TABLE 8—UMBILICAL RATIOS OF SMOOTH FORM OF *BORISSIAKOCERAS ORBICULATUM*

Diameter (mm.)	Umbilical ratios (%)	Number of specimens
1.6– 1.9	23.1	2
2 – 3.9	24.8	10
4 – 5.9	24.5	13
6 – 7.9	25.9	3
8 – 9.9	20.9	5
10 –10.3	20.5	3

Some individuals of both the smooth and noded forms have faint falcoid ribbing on the adult shells. These ribs are commonly closely spaced, irregular in height, and seem to represent bundles of raised growth lines. They are strongly arched forward on crossing the venter.

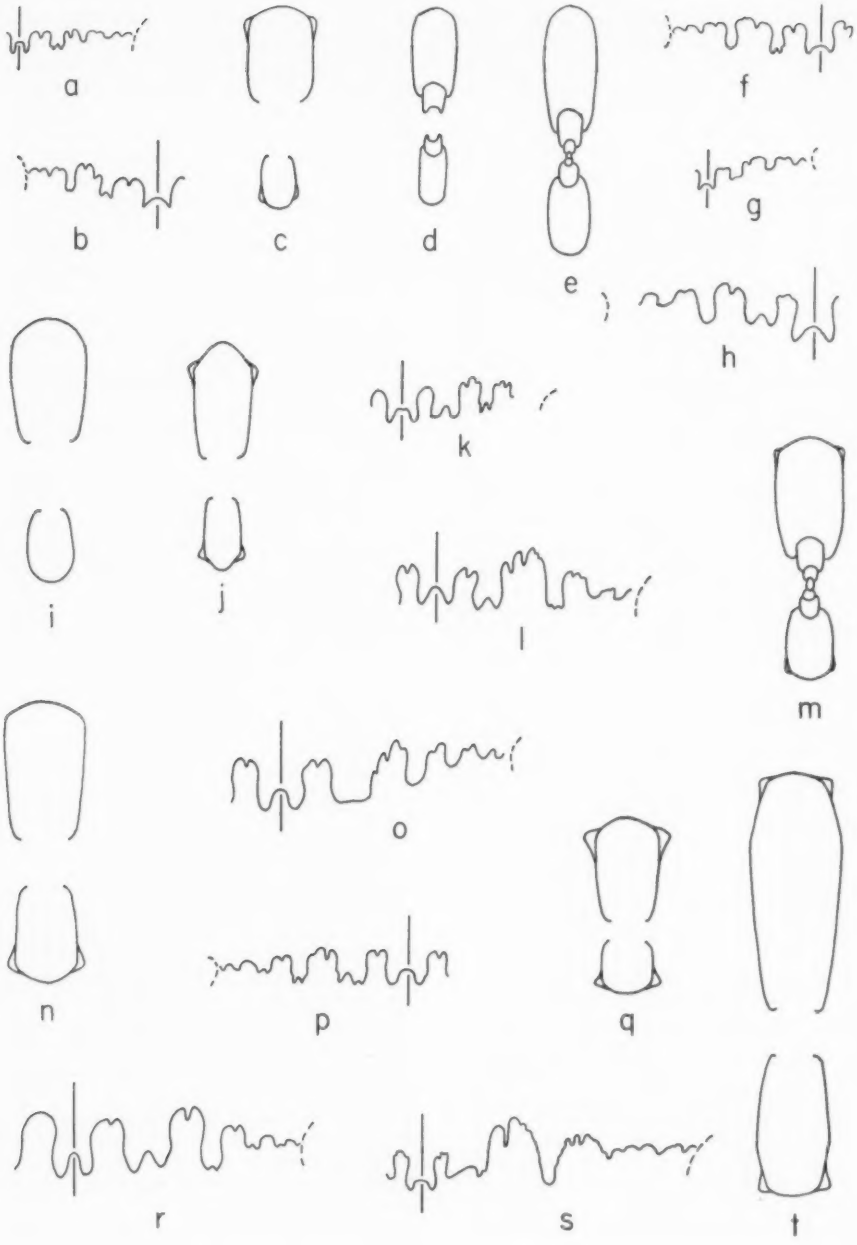
The aperture is sinuous and follows the growth lines. It is not constricted.

The adults range in diameter from about 11 mm. to a little more than 20 mm.

The suture has been adequately described by Stephenson. Sutures of 3 specimens from the Black Hills are shown as Text-figs. 5a,b,f.

The holotype, an adult, has a diameter of 22.5 mm., width of 4.5 mm., and umbilical diameter of 5 mm. (22.2 percent). Nodes, spaced 5 per half whorl, persist out to a diameter of 17.6 mm.

Remarks.—Borissiakoceras orbiculatum


a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
r
s
t

resembles only the species *B. mirable* Arkhangel'skii (1916, p. 55, pl. 8, figs. 2, 3) from the lower Turonian of Turkestan. Both are moderately evolute discoid forms of comparable size and suture. They differ chiefly by the greater umbilical width of *B. mirable* (37 percent) and the close spacing of the ventrolateral nodes.

Occurrence.—Stephenson's types came from the basal beds of the Eagle Ford shale at loc. 11740 on Walnut Creek, Tarrant County, Texas. The specimen (USNM 108834) figured by Stephenson from the northwest flank of the Black Hills came from the upper part of the Belle Fourche shale at loc. 12649 in Crook County, Wyoming, 19 miles west-southwest of Alzada, Montana. The large collection made by the writer came from the upper part of the Belle Fourche shale at loc. 22871 in Carter County, Montana, six miles northwest of Alzada.

Types.—Holotype, USNM 108832; figured paratypes, USNM 108833, 108834; plesiotypes, USNM 130827a-k, 130829; measured specimens, USNM 130828a-ww.

BORISSIAKOCERAS cf. B. ORBICULATUM Stephenson

Pl. 89, figs. 10-14; text-figs. 5g,i

Material.—The Greenhorn formation of the northeast flank of the Black Hills uplift in southeastern Montana has yielded two specimens of *Borissiakoceras*. Both have complete body chambers which occupy a little more than half a whorl.

Description.—The smaller specimen, from loc. 21794, is 6.7 mm. in diameter and 1.8 mm. in width. It has an umbilicus 1.4 mm. in diameter with a ratio of 20.9 percent. The venter is well rounded and merges evenly into the slightly flattened flanks. Nodes are lacking but faint falcoid ribbing on the body chamber is discernible in oblique light. The suture is very simple. This specimen is possibly a juvenile of the smooth variant of *B. orbiculatum*.

The larger specimen, from loc. 23062, has a diameter of 10.2 mm., a width of 2.5 mm., and an umbilical diameter of 2.5 mm. (24.5 percent). The venter is well rounded on the septate whorl and broadly rounded on the body chamber. The flanks, which are nearly flat, are farthest apart at their midline. The ventrolateral shoulder is poorly defined on the septate whorls but sharply defined on the body chamber. On the body chamber the ventrolateral shoulder contains low inconspicuous closely spaced arcuate clavi that merge into faint falcoid flank ribs. The aperture follows the shape of the ribs and growth lines.

Remarks.—The two specimens from the Greenhorn formation are younger than the collections of *B. orbiculatum* from the Belle Fourche shale and basal part of the Eagle Ford formation. The specimens seem to fall within the range of variation noted in the

TEXT-FIG. *5a–f—Borissiakoceras orbiculatum* Stephenson. *a*, suture, ×4, at diameter of 6.5 mm. of a specimen, USNM 130827i, from loc. 22871; *b*, suture, ×4, at diameter of 8.2 mm. of the noded form, USNM 130827b (Pl. 88, figs. 18–21); *c*, cross section, ×4, at diameter of 8 mm. of the same specimen; *d*, cross section, ×4, at diameter of 7.6 mm. of a specimen, USNM 130827j, from loc. 22871; *e*, cross section, ×4, at diameter of 9.8 mm. of the smooth variant, USNM 130827k, from loc. 22871; *f*, suture, ×4, at diameter of 8 mm. of a specimen, USNM 108834 (Pl. 88, figs. 38–40). *g, i—Borissiakoceras* cf. *B. orbiculatum* Stephenson. *g*, suture, ×8, at diameter of 4 mm. of a specimen, USNM 130830 (Pl. 89, figs. 10,11); *i*, cross section, ×4, at diameter of 10.2 mm. of a specimen, USNM 130831 (Pl. 89, figs. 12–14). *h, j–m—Binneyites carlilensis* Cobban, n. sp. *h*, suture, ×8, at diameter of 7 mm. of the holotype, USNM 130833 (Pl. 89, figs. 18–20); *j*, cross section, ×4, at diameter of 9 mm. of a paratype, USNM 130834 (Pl. 89, figs. 15–17); *k*, suture, ×4, of the same specimen; *l*, suture, ×4, of a paratype, USNM 130836, from loc. 21792; *m*, cross section (restored), ×4, of the same specimen. *n–p—Binneyites rugosus* Cobban, n. sp. *n*, cross section (restored), ×4, at diameter of 11 mm. of the holotype, USNM 130837 (Pl. 89, figs. 26–29); *o*, suture, ×8, at diameter of 7 mm. of the holotype; *p*, suture, ×8, at diameter of 5.4 mm. of a paratype, USNM 130838a (Pl. 89, figs. 30,31). *q, r—Binneyites nodosus* Cobban, n. sp. *q*, cross section, ×4, at diameter of 6.9 mm. of the holotype, USNM 130839 (Pl. 89, figs. 23–25); *r*, suture, ×8, at diameter of 6.5 mm. of the holotype. *s, t—Binneyites parkensis* Reeside. *s*, suture, ×4, at diameter of 16.5 mm. of a specimen, USNM 130832a (Pl. 89, figs. 32,33); *t*, cross section, ×4, at diameter of 16.3 mm. of the same specimen.

large collection of *B. orbiculatum* from loc. 22871, but a large collection from the Greenhorn formation might reveal significant differences. Until a larger collection is available, the Greenhorn forms will be compared to *B. orbiculatum*.

Occurrence.—Both specimens from the Greenhorn formation are from the valley of Five Mile Creek at locs. 21794 and 23062 in Carter County, Montana. They are from the basal Turonian zone of *Sciponoceras gracile* (Shumard).

Figured specimens.—USNM 130830, 130831.

Genus BINNEYITES Reeside 1927

Type species.—*Binneyites parkensis* Reeside.

Diagnosis.—Small discoid shells that have flattened flanks, broadly rounded venter, distinct ventrolateral shoulder, and small umbilicus. The suture, which is derived from *Borissiakoceras*, is simple for an ammonite. The ventral lobe is indented by a broad ventral saddle. The first lateral saddle, which is either bifid or undivided, is narrower than the ventral lobe. The first lateral lobe is bifid and about as wide as the ventral lobe. The second lateral saddle is higher than the first and commonly much wider. The second lateral lobe is long, bifid, and about half as wide as the first lateral lobe. The auxiliaries are rather simple and numerous; the saddle nearest the venter may be trifid.

BINNEYITES PARKENSIS Reeside
Pl. 89, figs. 32-37; text-figs. 5s,t

Binneyites parkensis REESIDE, 1927, p. 5, pl. 3, figs. 1–10; BASSE, 1952, p. 668, pl. 24, figs. 2, 2a; text-fig. 55–35; WRIGHT, 1957, p. L418, text-figs. 538-2a-c.

Diagnosis.—This species is characterized by its slender cross section, very small umbilicus, angular ventrolateral shoulder with small nodes, and suture pattern featured by a very narrow first lateral lobe. It is the largest known species.

Material.—The writer has seen less than half a dozen specimens of this species. Aside from the holotype, the best specimens are parts of two adults (Pl. 89, figs. 32–35) from the Cody shale at loc. 21097.

Description.—The earliest whorls are stout and well rounded. The flanks first flatten at a diameter of about 3 mm. As the shell enlarges, the whorls greatly increase their height in proportion to their width and the cross section of the adult body chamber may become three times as high as wide. The greatest width of the adult whorls is one-third of the distance from the venter to the umbilicus. This point of maximum width is marked by a faint angularity on the flank (Text-fig. 5t). The venter is well rounded on the early whorls but becomes broadly rounded on the final septate whorl. The ventrolateral shoulder is well defined by the beginning of the last septate whorl and becomes angular on the body chamber. Ventrolateral nodes first appear at a diameter of about 2.5 mm. They are small, pointed, slightly clavate, and number 5–7 per half whorl on the septate portion. They become smaller and more numerous on the adult body chamber where as many as 12 are present per half whorl.

The umbilicus is very small and sharply defined with steep walls. The umbilical ratio is about 6 percent for the holotype and 8 percent on a plesiotype (USNM 130832a, Pl. 89, fig. 32).

Low irregular falcoid ribs are present on the flanks of the body chamber of the holotype. These arch forward on crossing the venter. Similar ribbing is displayed on a body chamber (Pl. 89, fig. 34) from loc. 21097.

The suture is featured by a narrow first lateral saddle and broad bifid first lateral lobe. The second lateral saddle, which is bifid, is much larger than the first.

The holotype is a complete adult 25 mm. in diameter.

Occurrence.—The holotype of *Binneyites parkensis* came from 775 feet above the base of the Cody shale in Oregon Basin in the SW¼NE¼ sec. 6, T. 51 N., R. 100 W., Park County, Wyoming. Reeside's paratype (USNM 73268) came from the same part of the Cody shale farther northeast in Park County in sec. 24, T. 58 N., R. 97 W. Aside from these two localities, the writer is aware of the species only from the lower part of the Cody shale at loc. 21097 near Lander, Wyoming (Cobban, 1952, p. 758; Yenne & Pipiringos, 1954) and from the lower part of the Mancos shale at loc.

21427 near Vernal, Utah. The fossil seems to be of late Coniacian age and may be confined to the zone of *Scaphites depressus* Reeside.

Types.—Holotype, Yale Peabody Mus. No. 6420; paratype, USNM 73268; plesiotypes, USNM 130832a, 130832b.

BINNEYITES CARLILENSIS Cobban, n. sp.
Pl. 89, figs. 15-22; text-figs. 5h,j-m

Diagnosis.—A species of average size for the genus with rather narrow umbilicus, rounded venter, flattened flanks, and strong ventrolateral nodes. The suture is simple and marked by a broad first lateral lobe.

Material.—Four specimens are at hand from the basal beds of the Carlile shale of the Black Hills uplift. These came from limestone concretions and are undistorted. None is complete.

Description.—Between diameters of 0.7–1.6 mm. the whorls are broader than high but at all diameters greater than 1.6 or 1.7 mm. the height exceeds the width. The flanks, which are well rounded up to a shell diameter of about 2 mm., flatten a little at diameters between 2 and 3 mm. At great diameters they become flatter and somewhat divergent. The venter is very well rounded in all but the largest whorls which are broadly rounded. A well defined ventrolateral shoulder first appears at a diameter of about 3 mm. and persists at all greater diameters. Clavate nodes develop along the ventrolateral shoulder at a diameter between 3 and 4 mm. They are at first weak and number about 6 per half whorl; later they become strong and number 3 or 4 per half whorl; and, finally, on the body chamber, they weaken and increase to 5 or 6 per half whorl.

The umbilicus is sharply defined and has steep but sloping walls. The umbilical ratios, which could be determined for 3 of the specimens, are given together with the shell dimensions in the following table.

The suture is unusual in that it combines features of both *Binneyites* and *Borissiakoceras*. The ventral lobe is broad and divided by a wide ventral saddle. The first lateral saddle is like that of *Binneyites;* it is about half as broad as the ventral lobe and is bifid or undivided. The first lateral lobe is bifid and broader than the first lateral saddle but not as wide as the ventral lobe, a *Borissiakoceras* character. The second lateral saddle is higher and broader than the first and tends to be trifid. The second lateral lobe is about as long as the first but only half as wide. The third lateral saddle is as large as the first lateral saddle and may be trifid.

TABLE 9—DIMENSIONS AND UMBILICAL RATIOS OF *BINNEYITES CARLILENSIS*

USNM Specimen	Diameter (mm.)	Width (mm.)	Umbilicus (mm. & %)
130835	7.4	1.9	1.0 (13.5)
130834	8.5	2.6	1.7 (20.0)
130833	10.1	2.8	1.8 (17.8)

The holotype is an internal mold of a small adult that lacks part of the body chamber. It has a diameter of 10.1 mm., a width of 2.8 mm., and an umbilical diameter of 1.8 mm. (17.8 percent). The last septate whorl has large widely separated ventrolateral nodes. These nodes weaken at the base of the body chamber and become more numerous and elongated.

Remarks.—*Binneyites carlilensis* is readily distinguished from *B. parkensis* Reeside by its stouter cross section, larger umbilical ratio, more widely spaced nodes, and suture with a broader first lateral saddle.

Occurrence.—The species is known only from locs. 21181, 21591, and 21792, on the northeast, northwest, and west flanks of the Black Hills uplift in South Dakota and Wyoming. There it occurs with *Inoceramus cuvierii* Sowerby, *Collignoniceras woollgari* (Mantell), and *Scaphites larvaeformis* Meek & Hayden, of middle Turonian age.

Types.—Holotype, USNM 130833; paratypes, USNM 130834–130836.

BINNEYITES APLATUS (Morrow)

Borissiakoceras aplatum MORROW, 1935, p. 465, Pl. 49, figs. 5a,5b; pl. 50, fig. 6; text-fig. 7.

Morrow described this as a very small species that has flat nearly parallel flanks, broadly rounded venter, and faint ventrolateral shoulder. Nodes are said to be lacking. The umbilicus is very small and has a ratio of about 9 percent judging from Morrow's figure. The suture is simple and has the ventral and first lateral lobes of about equal width. Morrow gives the dimensions

of the holotype as 7 mm. in diameter and 2.2 mm. in thickness. The specimen came from a calcareous concretion in the upper part of the Blue Hill shale member of the Carlile shale near Tipton, Kansas.

The writer places Morrow's species in *Binneyites* because of the small umbilical ratio and the suture which has ventral and first lateral lobes of nearly equal size. The ventrolateral shoulder is normal for *Binneyites* but the lack of nodes is puzzling. Possibly the specimen is a juvenile that has not attained the noded stage.

Binneyites aplatus is very rare. Aside from the holotype, Morrow had only two impressions of the venter. The writer has collected extensively from the Blue Hill shale member in Kansas and from the equivalent rocks in other western States, but has seen only one crushed specimen of the family Binneyitidae (loc. 21182), and this has been recorded as *Borissiakoceras* sp. (Cobban, 1951, p. 2188). The Blue Hill shale member is about middle Turonian in age and represents the zone of *Scaphites carlilensis* Morrow and *Collignoniceras hyatti* (Stanton).

BINNEYITES NODOSUS Cobban, n. sp.
Pl. 89, figs. 23–25; text-figs. 5q,r

Diagnosis.—A stout species with strong closely spaced ventrolateral nodes. The suture has long lobes and saddles; the first and second lateral lobes tend to be bifid and of equal size.

Material.—This species is based on a single septate specimen from the Marias River shale near Shelby, Montana. The specimen, which is well preserved and uncrushed, came from a limestone concretion.

Description.—The holotype has a diameter of 6.8 mm. and width of 2.6 mm. between nodes and 3.2 mm. including nodes. The umbilicus has steeply sloping sides and a diameter of 0.7 mm. (10.3 percent). The whorls are thick and flat sided. The venter is wide, broadly rounded, and separated from the flanks by a subangular shoulder. Nodes spaced 6 per half whorl are present along the ventrolateral shoulder. These are round but sharp on the older part of the shell and slightly clavate on the younger part.

The suture has a moderately large ventral lobe that is a little longer than wide. The ventral saddle is narrow and deep. The first lateral saddle, which is slightly narrower than the ventral lobe, is bifid on one side of the shell and undivided on the other. The first lateral lobe is bifid and as large as the ventral lobe. The second lateral saddle is bifid and a little higher than the first but about the same width. The second lateral lobe is bifid and about half as wide as the first. The third lateral saddle is bifid and a little narrower than the second but about half as high. The third and fourth lateral lobes are bifid and nearly as wide as the second but much shorter. The fourth lateral saddle is undivided and as wide as the third but shorter.

Remarks.—The stout cross section and numerous nodes readily separate this species from *B. parkensis* and *B. carlilensis*. The suture is unusual by having the first and second lateral saddles of equal width and nearly as wide as the ventral lobe.

Occurrence.—The species is known only from loc. 21422 south of Shelby, Montana, where it is associated with *Inoceramus deformis* Meek and *Scaphites preventricosus* Cobban of early Coniacian age.

Type.—Holotype, USNM 130839.

BINNEYITES RUGOSUS Cobban, n. sp.
Pl. 89, figs. 26-31; text-figs. 5n-p

Diagnosis.—This is a small stout species that has a suture characterized by a somewhat broad first lateral saddle which is bifid. The venter is crossed by forwardly arched ribs of irregular height and spacing.

Material.—Nine specimens are at hand from the upper part of the Marias River shale at loc. 21425 near Shelby, Montana. They came from linestone concretions and are largely uncrushed.

Description.—The early whorls are well rounded with stout cross sections. At a diameter between 1.7-2.5 mm. the flanks begin to flatten and the height of the whorls increases more rapidly than the width. A well defined ventrolateral shoulder appears at a diameter of about 3 mm. and persists through all the rest of the growth stages. The adult has a broadly rounded venter, angular ventrolateral shoulder, and flat slightly divergent flanks. The adult umbilicus is about the same size as that of

TABLE 10—DIMENSIONS AND UMBILICAL RATIOS OF *BINNEYITES RUGOSUS*

USNM Specimen	Diameter (mm.)	Width (mm.)	Umbilicus (mm. & %)
130838b	1.8	0.8	0.3 (16.7)
130838c	2.8	1.4	0.4 (14.3)
130838d	2.9	1.2	0.4 (13.8)
130838e	3.4	1.5	0.4 (11.8)
130838f	3.8	1.3	0.5 (13.2)
130838g	5.0	2.1	0.6 (12.0)
130838a	5.8	2.0	0.7 (12.1)
130837	7.8	3.0	1.1 (14.1)

the early whorls but has more abrupt sides.

Flank and ventral ribbing ordinarily appears at a diameter of about 3 mm. These ribs follow the falcoid growth lines and are irregular in height and spacing. They are at first weak but become stronger on the adult body chamber. They are most conspicuous on the venter which they cross with a pronounced forward arching. Nodes may form on the ventrolateral shoulder at a diameter as small as 3.5 mm. or at some diameter greater than 6 mm.

The holotype (USNM 130837) is an adult which has part of its body chamber broken and pushed down onto the septate whorls. It is 10.8 mm. in diameter and 3.3 mm. in width. All whorls are stout; the outer one has a broadly rounded venter, angular ventrolateral shoulder, and flat slightly divergent flanks. The umbilicus has steep flanks and a ratio of 14 percent at a shell diameter of 7.8 mm. Rather strong clavate nodes, spaced 5 per half whorl, are present on the ventrolateral shoulder of the last septate whorl. These weaken and become closely spaced on the older half of the body chamber where they become arcuate and arranged along the ventrolateral shoulder with a forward tilt. On the younger half of the body chamber the nodes are merely accentuated parts of falcoid ribs where the latter cross the ventrolateral shoulder. These ribs are poorly developed and weak on the older part of the body chamber but become stronger on the younger part. All are of irregular height and spacing; they are strongest on the venter which they cross with a forward arching.

The suture is typical of the genus. The ventral lobe is broad and contains a deep ventral saddle. The first lateral saddle is bifid and about half as wide as the ventral lobe. The first lateral lobe is poorly bifid and nearly the size of the ventral lobe. The second lateral saddle is higher and broader than the first and somewhat trifid. The second lateral lobe is half as wide as the first and may be bifid. The third and fourth lateral saddles are about half as long and wide as the second and tend to be bifid. The third and fourth lateral lobes are nearly as wide as the second but less than half as long.

Remarks.—*Binneyites rugosus* is most closely related to its immediate ancestor *B. parkensis* from which it can be distinguished by its stouter whorls, stronger ornament, and suture that has a broader first lateral saddle which is bifid. In addition the suture has better defined lobes and saddles beyond the second lateral lobe.

Occurrence.—This species is known only from loc. 21425 about 11 miles southwest of Shelby, Montana. There it occurs with *Clioscaphites vermiformis* (Meek & Hayden) of early Santonian age.

Types.—Holotype, USNM 130837; paratypes, USNM 130838a-h.

REFERENCES

ADKINS, W. S., 1933, The Mesozoic systems in Texas, *in* Sellards, E. H., Adkins, W. S. & Plummer, F. B., The geology of Texas: Texas Univ. Bull. 3232, p. 239–518, 1932.

—— & LOZO, F. E., 1951, Stratigraphy of the Woodbine and Eagle Ford, Waco area, Texas: Fondren Sci. Ser., no. 4, p. 105–161, 6 pls.

ARKHANGEL'SKII, A. D., 1916, Les mollusques du Crétacé Supérieur du Turkestan: Com. Géol. Mém., n. s., v. 152, p. 1–57, pls. 1–8.

BASSE, ELIANE, 1952, Classe des Céphalopodes, *in* Piveteau, Jean, Traité de Paléontologie, Part 2, p. 461–688, 24 pls.

COBBAN, W. A., 1951, Colorado shale of central and northwestern Montana and equivalent rocks of Black Hills: Am. Assoc. Petroleum Geologists Bull., v. 35, no. 10, p. 2170–2198.

——, 1952, A new Upper Cretaceous ammonite genus from Wyoming and Utah: Jour. Paleontology, v. 26, no. 5, p. 758–760, pl. 110.

—— & REESIDE, J. B., JR., 1952, Correlation of the Cretaceous formations of the Western Interior of the United States: Geol. Soc. America Bull., v. 63, no. 10, p. 1011–1044, 1 pl.

DANE, C. H., PIERCE, W. G. & REESIDE, J. B., JR., 1937, The stratigraphy of the Upper Cretaceous rocks north of the Arkansas River in eastern Colorado: U. S. Geol. Survey Prof. Paper 186-K, p. 207–232, pls. 64, 65.

GLAZUNOVA, A. E. & LUPPOV, N. P., 1958, Superfamily Tissotiaceae, *in* Luppov, N. P., &

Drushchitz, V. V., Mollusca-Cephalopoda II: Principles of Paleontology-Handbook for Paleontologists and Geologists of the U.S.S.R., Y. A. Orlov, ed., v. 6, pt. 2, p. 128–130, pl. 64 (in Russian).

GRYC, GEORGE, 1951, Paleontology, *in* Payne, T. G. and others, Geology of the Arctic slope of Alaska: U. S. Geol. Survey Oil and Gas Inv. Map OM-126.

HOSE, R. K., 1955, Geology of the Crazy Woman Creek area, Johnson County, Wyoming: U. S. Geol. Survey Bull. 1027-B, p. 33–118.

MORROW, A. L., 1935, Cephalopods from the Upper Cretaceous of Kansas: Jour. Paleontology, v. 9, no. 6, p. 463–473, pls. 49–53.

REAGAN, A. B., 1924, Cretacic Mollusca of Pacific slope: Pan-Am. Geologist, v. 41, p. 179–190, pls. 18–21.

REESIDE, J. B., JR., 1927, Cephalopods from the lower part of the Cody shale of Oregon Basin, Wyoming: U. S. Geol. Survey Prof. Paper 150-A, p. 1–19, pls. 1–8.

SMITH, J. P., 1914, The Middle Triassic marine invertebrate faunas of North America: U. S. Geol. Survey Prof. Paper 83, 254 p.

STELCK, C. R. & WALL, J. H., 1954, Kaskapau Foraminifera from Peace River area of western Canada: Albert Research Council Rept. 68, 38 p., 2 pls.

STEPHENSON, L. W., 1952, Larger invertebrate fossils of the Woodbine formation (Cenomanian) of Texas: U. S. Geol. Survey Prof. Paper 242, 226 p., 59 pls., 1953.

——, 1955, Basal Eagle Ford fauna (Cenomanian) in Johnson and Tarrant Counties, Texas: U. S. Geol. Survey Prof. Paper 274-C, p. 53–67, pls. 4–7.

WARREN, P. S. & STELCK, C. R., 1958, Lower Cenomanian Ammonoidea and Pelecypoda from Peace River area, western Canada: Alberta Research Council Rept., Geol. Div., Bull. 2, p. 36–51, pls. 5–16.

WRIGHT, C. W., 1952, A Classification of the Cretaceous ammonites: Jour. Paleontology, v. 26, no. 2, p. 213–222.

——, 1957, Hoplitaceae, *in* Arkell, W. J., Kummel, Bernard & Wright, C. W., Mesozoic Ammonoidea: Treatise on Invertebrate Paleontology, R. C. Moore, ed., Part L, Mollusca 4, p. L80–L465.

YENNE, K. A. & PIPIRINGOS, G. N., 1954, Stratigraphic sections of Cody shale and younger Cretaceous and Paleocene rocks in the Wind River Basin, Fremont County, Wyoming: U. S. Geol. Survey, Oil & Gas Inv. Chart OC49.

EXPLANATION OF PLATE 89

FIGS. *1–9—Borissiakoceras compressum* Cobban, n. sp. *1,2*, Side and rear views of a septate internal mold (USNM 130824) of the noded variant from loc. 528, ×1; *3,4*, side and rear views of a strongly noded septate specimen (USNM 130822h) from loc. 23462, ×1; *5–7*, side, front, and rear views of an internal mold (USNM 130822i) that has unusually strong flank ribs, from loc. 23462, ×1; *8,9*, side and rear views of a smooth juvenile (USNM 130822j) from loc. 23462, ×1.

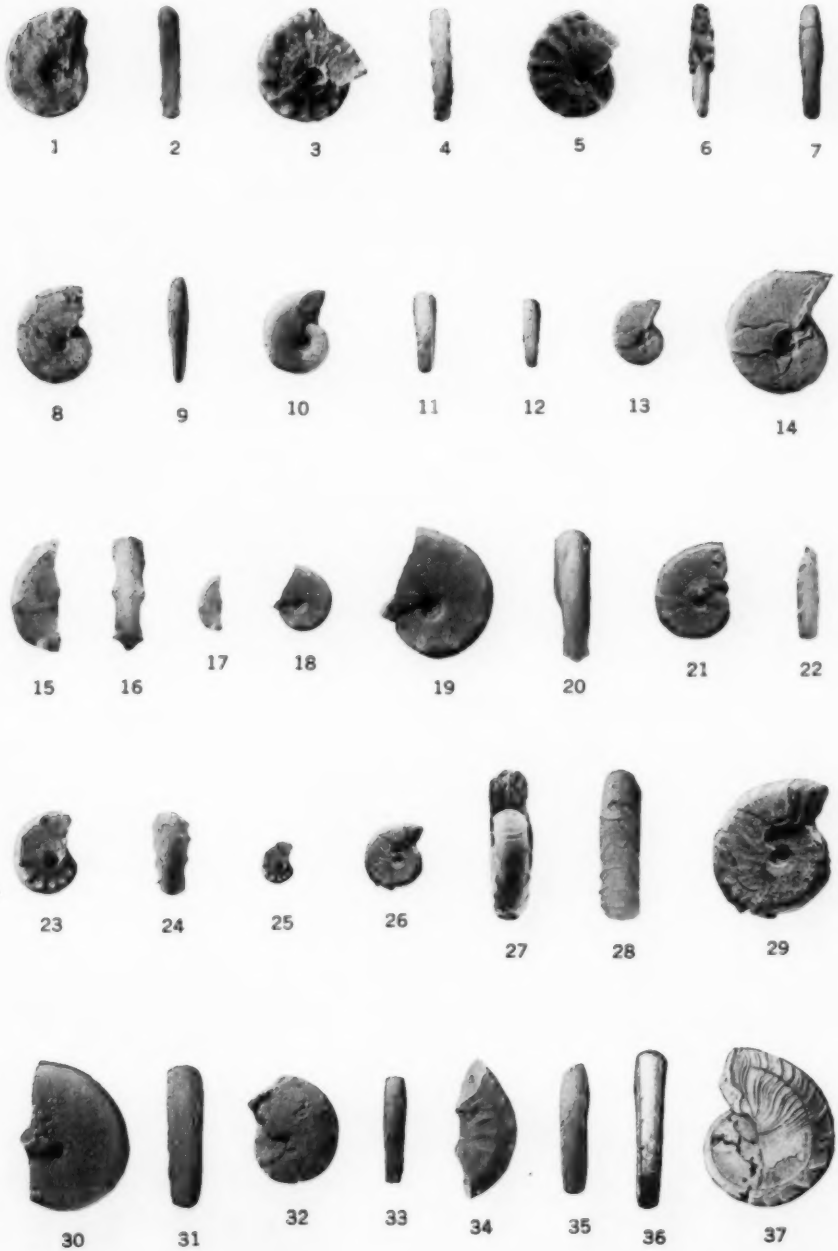
10–14—Borissiakoceras cf. *B. orbiculatum* Stephenson. *10,11*, Side and rear views of an internal mold of a small specimen (USNM 130830) that has a nearly complete weakly ribbed body chamber, from loc. 21794, ×2; *12,13*, rear and side views of an adult (USNM 130831) with complete body chamber, from loc. 23062, ×1; *14*, side view of same specimen, ×2.

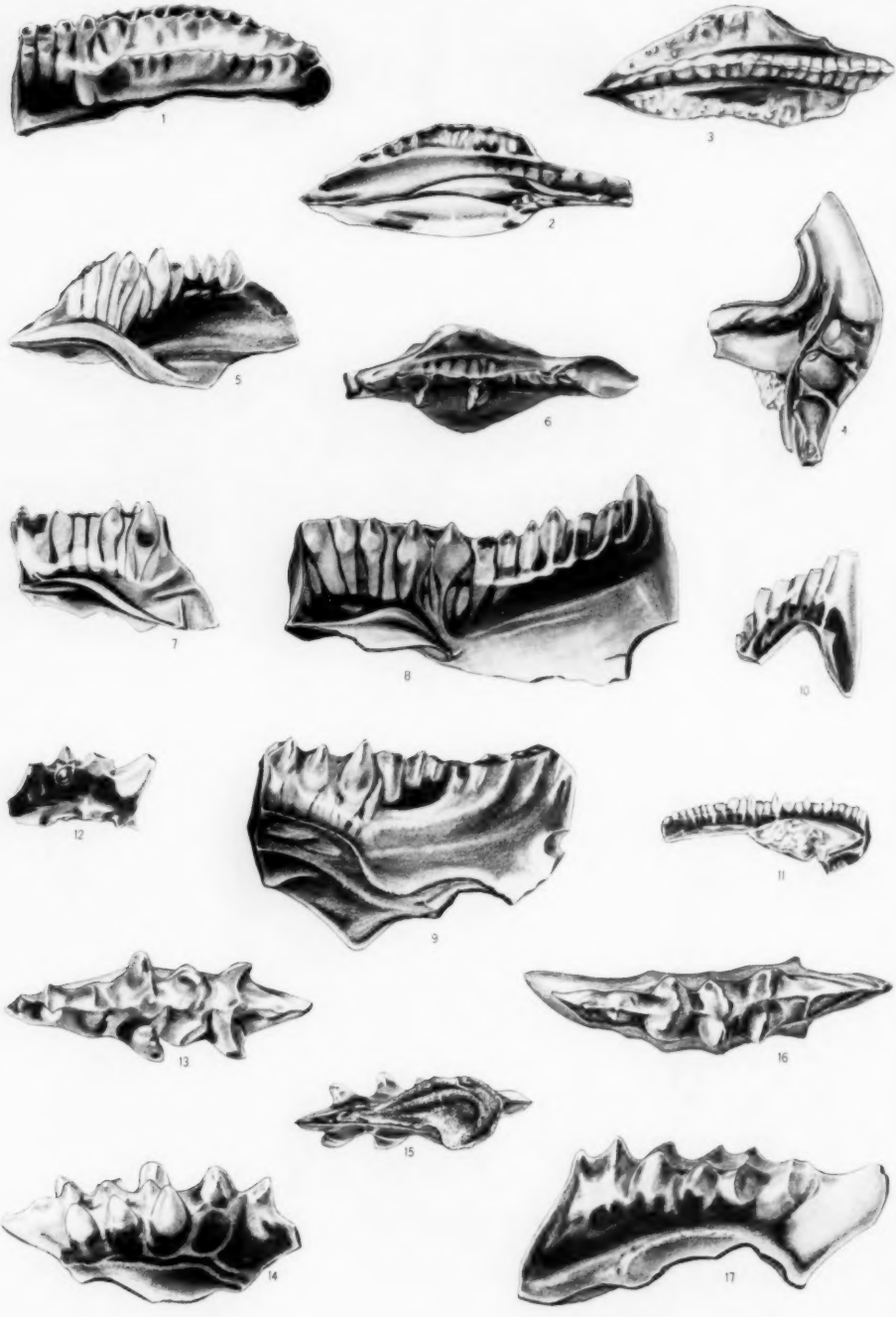
15–22—Binneyites carlilensis Cobban, n. sp. *15,16*, Side and rear views of a septate internal mold (USNM 130834) showing the strong widely spaced nodes, from loc. 21591, ×2; *17*, side view of the same specimen, ×1; *18*, side view of the holotype (USNM 130833), from loc. 21591, ×1; *19,20*, side and rear views of the holotype, ×2; *21,22*, side and rear views of a small specimen (USNM 130835), from loc. 21181, ×2.

23–25—Binneyites nodosus Cobban, n. sp., from loc. 21422. *23,24*, Side and rear views of the holotype (USNM 130839), ×2; *25*, side view of holotype, ×1.

26–31—Binneyites rugosus Cobban, n. sp., from loc. 21425. *26*, Side view of holotype (USNM 130837), ×1; *27–29*, front, rear, and side views of holotype, ×2; *30,31*, side and rear views of a small specimen (USNM 130838a), ×4.

32–37—Binneyites parkensis Reeside. *32,33*, Side and rear views of a septate internal mold (USNM 130832a), from loc. 21097, ×1; *34,35*, side and rear views of part of an adult body chamber (USNM 130832b), from loc. 21097, ×1; *36,37*, rear and side views of the holotype (Yale Peabody Mus. No. 6420), ×1, after Reeside.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37



JOURNAL OF PALEONTOLOGY, V. 35, NO. 4, P. 759–768, PL. 90, 1 TEXT-FIG., JULY, 1961

UPPER DEVONIAN CONODONTS FROM BIGHORN MOUNTAINS, WYOMING

R. L. ETHINGTON, W. M. FURNISH AND J. R. WINGERT
Arizona State University, Tempe, State University of Iowa, Iowa City, and Standard Oil Company of California, Salt Lake City

ABSTRACT—A small collection of Upper Devonian conodonts from Cottonwood Canyon on the west side of the Bighorn Mountains, Wyoming, is describe.d The majority of the species are the same as those reported from the Darby Formation in the Wind River Mountains in western Wyoming. General correlation with the Saverton of Missouri and part of the *Clymenia*-Stufe of Europe is indicated.

INTRODUCTION

DISCOVERY of Devonian rocks in Cottonwood Canyon on the northwest side of the Bighorn Mountains, Wyoming, was reported by Blackstone & McGrew (1954). These authors noted the occurrence of several genera of conodonts in a thin black fissile shale at the top of the Devonian section at this locality. Samples collected from this bed by the junior authors yielded a small conodont fauna consisting of ten genera and eleven species. The fauna is almost identical to that reported by Klapper (1958) from the Darby Formation in the Wind River Mountains.

STRATIGRAPHIC SETTING

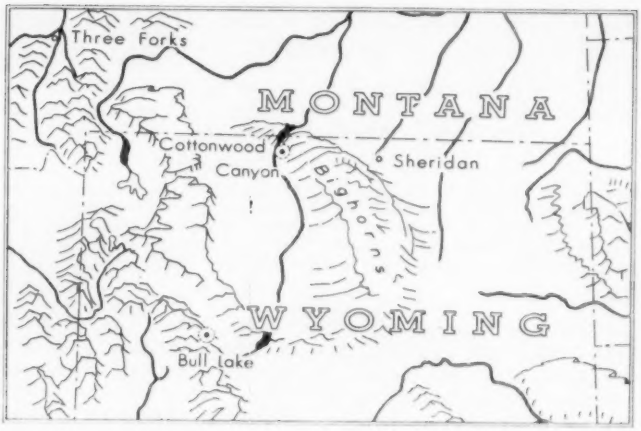
Occurrence of Devonian rocks in southwestern Montana was first reported by Peale (1893), who described the stratigraphic section near Logan, Montana, and subdivided it into a lower carbonate Jefferson Formation and an upper clastic Threeforks Formation. Blackwelder (1918) disagreed with use of Jefferson and Threeforks for the Devonian rocks of western Wyoming and proposed the Darby Formation for strata cropping out on the west side of the Teton Range. Subsequent workers have generally applied the name Darby to Upper Devonian exposures in western Wyoming, whereas rocks of approximately the same age in Montana and the Williston Basin have been referred to the Jefferson and Threeforks.

Sloss & Laird (1947) restudied the type area of the Jefferson and Threeforks and divided the former into a lower Limestone Member and an upper Dolomite Member. Corals of the upper member were considered to be suggestive of the "Hackberry" of Iowa. The work was restricted to western and central Montana and did not extend into northern Wyoming. In their interpretation (fig. 2, p. 1408) the Threeforks thins eastward from the type area at Logan. Similar eastward thinning of the Dolomite Member of the Jefferson is compensated by increase in thickness of the underlying Limestone Member.

Andrichuk (1956) correlated the lower Darby of the Wind River Mountains with the upper Dolomite Member of the Jefferson as defined by Sloss & Laird. He con-

EXPLANATION OF PLATE 90

FIGS. *1–3—Polygnathus wyomingensis* Klapper. *1*, lateral view; *2*, aboral view; *3*, oral view; all ×60. S.U.I. 10333.
4—Ligonodina robusta Branson & Mehl. Outer lateral view. ×20. S.U.I. 10323.
5–9—Spathognathodus aculeatus (Branson & Mehl). *5,7–9*, lateral views of fragmentary specimens, ×55, *6*, oral view, ×50. S.U.I. 10335–10339.
10—Neoprioniodus sp. Lateral view, ×55, S.U.I. 10324.
11—Apatognathus varians Branson & Mehl. Lateral view ×60. S.U.I. 10321.
12–17—Pelekysgnathus darbyensis (Klapper). *12*, lateral view of immature specimen, ×60; *13,14*, oral and lateral views of nearly complete specimen, ×50; *15*, aboral view, ×50; *16,17*, oral and lateral views of complete specimen, ×55. S.U.I. 10328–10331.



TEXT-FIG. 1—Index map.

cluded that the Darby represents the maximum transgression of the Upper Devonian sea onto the Wyoming shelf from the geosyncline to the west. The eastern shoreline of this sea was located in the southern Wind River Mountains and the Wind River Basin. He concluded that the Darby disappears in the southeastern part of the Bighorn Basin.

Penetration of Devonian rocks by wells in the Bighorn Basin was reported by Mills (1956). These beds were correlated with upper Jefferson of the Williston Basin.

Sandberg & Hammon (1958) considered the Jefferson in the Williston Basin to be a group consisting of the Duperow and Birdbear formations. The Jefferson was believed to be represented in the northern Bighorn Mountains only by the Duperow, the overlying Birdbear equivalent having been removed by pre-Mississippian erosion. Shaly and sandy beds in the upper part of the Devonian section of north-central Wyoming were interpreted as the near-shore facies of the Duperow deposited at the time of maximum advance of the Jefferson sea. These authors concluded that the Threeforks is less widespread in occurrence than the Jefferson, in part because of recession of seas during Threeforks time and also owing to extensive post-Devonian erosion.

Presence of Devonian strata in Big Goose Creek Ridge on the eastern flank of the Bighorn Mountains was inferred by Tomlinson (1917), although he was unable conclusively to demonstrate their age. Blackstone & McGrew (1954) reported the discovery of a Devonian section in the walls of Cottonwood Canyon on the west side of the Bighorns. The lower part of the exposure was correlated on the basis of lithologic similarity, stratigraphic position and contained vertebrate fossils with the channel deposits described by Dorf (1934) at Beartooth Butte. There are three of these localized deposits in the canyon within depressions of the Ordovician Bighorn Formation, and below the main body of the Devonian. The remainder of the Devonian outcrop was divided into a lower carbonate sequence overlain by a series of clastic strata. On the basis of similar lithology, these beds were tentatively correlated with the Jefferson and Threeforks respectively. Richards (1955, p. 14–21) described two sections of Devonian rocks in Big Horn County, Montana, just a few miles north of the Cottonwood Canyon locality. In that vicinity, measured intervals and wells show approximately 200 feet of carbonate with minor amounts of shale, siltstone, and sandstone. These Devonian strata were identified as undifferentiated Jefferson and Threeforks. Some few poorly preserved corals and

brachiopods indicate, or are compatible with, a Middle and Upper Devonian age (Richards, 1955, p. 20–21).

Larimer (1959) identified about 50 feet of Devonian exposure on South Fork of Rock Creek on the east side of the Bighorns. Fish plates from the top of the Devonian at this locality are of a general type known elsewhere from the Jefferson. Well exposed sections have since been examined above Dayton on new road cuts of Highway 14 and in Tongue River Canyon. All of these sections are in the general vicinity of Tomlinson's (1917) section near Goose Creek.

Thus it appears that regional correlations of the Devonian within the Williston Basin seem to be reasonably secure (e.g., Sandberg & Hammond, 1958) but the relationships near the southern margin are less certain. Megafossils are generally poorly preserved or lacking; the abundant fish remains of the Beartooth Butte Formation are an exception but they have been determined to be pre-Upper Devonian (Dorf, 1934). Practically all the Darby Formation in the northern Wind River section has been correlated with Threeforks by Andrichuk (1956, p. 46). Although Sandberg & Hammond (1958, p. 2300) regard the dolomites of the Bighorn region as Duperow (lower Jefferson), the conodont faunas indicate that these two sections, in the Wind River and Bighorn mountains, are probably the same age. The distinctive black shale at the top of the Devonian mentioned by Andrichuk (1951, p. 2382) may represent the conodont-bearing units of the uplifts and thus overlie true Threeforks. Occurrence of *Platyclymenia* in Threeforks Shale of the type area has been generally interpreted to mean equivalence with Oberdevon Stufe III–IV of Germany. As Klapper (1958, p. 1085) previously concluded, the conodont faunas directly below the Madison Formation (Mississippian) are probably correlative with Oberdevon Stufe V, the *Clymenia*-Zone of Schindewolf (1957, p. 38).

CONODONT FAUNA

Faunal assemblage.—A small number of conodonts has been recovered by kerosene treatment of shale taken from the top foot of the Devonian section exposed in Cottonwood Canyon (Center S½ Sec. 34, T. 57 N., R. 93 W.). Most species are represented by only a few specimens, but others such as *Spathognathodus aculeatus* and *Polygnathus wyomingensis* are moderately abundant.

Apatognathus varians Branson & Mehl
Hindeodella spp.
Ligonodina robusta Branson & Mehl
Neoprioniodus sp.
Ozarkodina regularis Branson & Mehl
Palmatolepis sp.
Pelekysgnathus darbyensis (Klapper)
Polygnathus triangularis Branson & Mehl
Polygnathus wyomingensis Klapper
Scolopodus? sp.
Spathognathodus aculeatus (Branson & Mehl)

Significance.—The Devonian conodont fauna from Cottonwood Canyon almost corresponds species-for-species to that reported from the Darby (Klapper, 1958). Similarity of the two faunas is further emphasized by the abundant occurrence of *Spathognathodus aculeatus* and common *Polygnathus wyomingensis* in both localities.

Spathognathodus aculeatus was first described from the Saverton of Missouri. It is very similar to *Spathognathodus tridentatus*, which is known in North America from the Hannibal and English River. Both species have been reported from the Devonian of Europe where they occur most abundantly in the *Clymenia*-Stufe, although *S. tridentatus* ranges as high as the *Wocklumeria*-Stufe (Helms, 1959).

Apatognathus varians and *Polygnathus triangularis* occur in the Saverton and the Darby. The former is also known from the *Clymenia*-Stufe of southern Germany. *Polygnathus triangularis* has been reported from the *Pericyclus*-Stufe (cuIII) of Europe (Bischoff, 1957). *Ligonodina robusta* is previously known from the Saverton and the Maple Mill.

Presence of *Scolopodus?* is of uncertain significance. Such simple distacodid types occur in greatest abundance and diversity in the Ordovician and Silurian, but a few forms are known from the Devonian. Most of these younger species are atypical of the Ordovician genera and only questionably identified with them. Additional studies of Silurian conodonts, as yet only poorly known, may clarify the systematic relation-

TABLE 1—SUGGESTED CORRELATION OF SOME UPPER DEVONIAN FORMATIONS OF THE ROCKY MOUNTAINS AND RELATED UNITS. THE WYOMING CONODONT FAUNAS OCCUR AT THE TOP OF THE STRATA IDENTIFIED AS DARBY FORMATION. IN THIS SAME AREA, THE BEAR TOOTH BUTTE FORMATION OF PROBABLE LOWER DEVONIAN AGE IS FOUND LOCALLY AND UNCONFORMABLY BELOW THE DARBY

	Western Wyoming	Southwest Montana	Williston Basin		Upper Mississippi	Ammonoid Zones Germany
LOWER MISSISSIPPIAN—MADISON LMST., etc.						Gattendorfia
UPPER DEVONIAN	DARBY FORMATION	THREEFORKS FORMATION	THREEFORKS FORMATION		LOUISIANA	Wocklumeria VI
					SAVERTON	Clymenia V
					GRASSY	Platyclymenia III & IV
		JEFFERSON DOLOMITE	JEFFERSON	Birdbear Formation	CREEK	Cheiloceras II
				Duperow Formation		Manticoceras I
			SOURIS RIVER FORMATION			
MIDDLE OR LOWER DEVONIAN						

ships between Devonian and Ordovician distacodids.

In North America *Pelekysgnathus* has been previously described from the Maple Mill. Representatives of this genus have been reported to range from upper *Manticoceras*-Stufe (toIδ) through *Clymenia*-Stufe (toV) in Germany (Bischoff & Ziegler, 1957). As stated by Klapper, *P. darbyensis* is close to *Icriodus cornutus* Sannemann which ranges from *Manticoceras*-Stufe to *Cheiloceras*-Stufe in the European section. However, *P. darbyensis* represents an advanced form among species transitional between *Icriodus* and *Pelekysgnathus* and therefore suggests a somewhat younger age than *I. cornutus*.

The single *Palmatolepis* in the Cottonwood Canyon fauna appears to be a typical representative of the subgenus *Manticolepis* which has been previously reported from the early Upper Devonian (Müller, 1956). This occurrence is in sharp contrast to the other genera in this fauna which are indicative of Famennian age. *Palmatolepis* is represented in the very similar Darby fauna by *P. gonioclymeniae*, a late Upper Devonian species which is consistent with the associated fauna. Possibly the Cottonwood Canyon specimen has been reworked from older beds.

Collectively the Devonian conodont fauna from the northern Bighorn Mountains is almost identical to that of the Darby of western Wyoming. Probable correlation with the Saverton of Missouri is suggested. Comparison with European conodont faunas indicates general equivalence to part of the *Clymenia*-Stufe of Germany—the *Gonioclymenia*-Stufe (toV) of authors.

ACKNOWLEDGMENTS

We are grateful to Charles Collinson and Alan J. Scott for suggestions regarding classification of Upper Devonian conodonts. Gilbert Klapper read the manuscript and advised us on taxonomic and stratigraphic problems. Funds for expenses were provided by the Graduate College, State University of Iowa, and Socony Mobil Oil Company. Alan Blizzard prepared pencil drawings for for the plate. All type material is deposited in the Department of Geology, State University of Iowa. Fay's "Catalogue of cono-

donts" (Kansas Univ. Paleont. Contr., Vertebrata, art. 3) has been employed generally for synonymies prior to 1949.

SYSTEMATIC PALEONTOLOGY

Genus APATOGNATHUS Branson & Mehl, 1934

Type species: *Apatognathus varians* Branson & Mehl, 1934.

APATOGNATHUS VARIANS Branson & Mehl
Pl. 90, fig. 11

Apatognathus varians BRANSON & MEHL, 1934, Missouri Univ. Studies, v. 8, p. 201, 202, pl. 17, figs. 1–3; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 66; BISCHOFF & ZIEGLER, 1956, Hess. Landesamt Bodenforsch. Notizbl., Bd. 84, p. 145, pl. 14, fig. 3; KLAPPER, 1958, Jour. Paleontology, v. 32, p. 1085, pl. 141, figs. 6,8.

Apatagnothus [*sic*] sp. BLACKSTONE & MCGREW, 1954, Billings Geol. Soc., Guidebook, 5th Ann. Field Conf., p. 39,42.

This species includes dental units consisting of highly arched narrow denticulate bars whose limbs diverge at an angle of approximately 40°. An apical denticle, seated at the crest of the arched bar, is sharply curved inward and nearly normal to the plane of the limbs. Outer face of the apical denticle is broadly semicircular in section; inner face is a semicircle of shorter radius bordered by a longitudinal shoulder on either side. Oral edges of the limbs are directed inward and bear closely crowded conical denticles which are set deeply into the bars. The free portions of the denticles are discrete. To compensate for close crowding, the denticles are diagonally offset along the length of the limbs in cycles of three. At the crest of the arch, a thin lamella extends between the two limbs on the outer side of the unit. No basal cavity or groove is present, and the aboral surfaces of the limbs are broad and blunt.

Remarks.—Although moderately abundant in the fauna, none of the specimens is complete. They appear to be identical to those previously described from the Saverton (Grassy Creek) of Missouri and from the Darby of the Wind River Mountains, Wyoming. The transverse offset of the denticles along the limbs is suggestive of relationship to *Diplododella*. This species differs from *A. inversus* Sannemann in the configuration of the limbs and absence of a basal cavity and from *A. lipperti* Bischoff whose denticles alternate in size.

Repository.—Figured hypotype, S.U.I., 10321.

Genus LIGONODINA Ulrich & Bassler, 1926

Type species: *Hindeodella subtilis* Ulrich & Bassler, 1926.

HINDEODELLA spp.

Numerous fragments, none specifically identifiable, were recovered. Characters of denticulation suggest the presence of several species. Some of the specimens appear to be conspecific with material from the Darby described by Klapper (1958).

Repository.—Unfigured specimens, S.U.I., 10423.

Genus LIGONODINA Ulrich & Bassler, 1926

Type species: *Ligonodina pectinata* Ulrich & Bassler, 1926.

LIGONODINA ROBUSTA Branson & Mehl
Pl. 90, fig. 4

Ligonodina robusta BRANSON & MEHL, 1934, Univ. Missouri Studies, v. 8, p. 200–201, pl. 15, fig. 30; THOMAS, 1949, Geol. Soc. America, Bull., v. 60, p. 408, pl. 1, fig. 30; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 119; BISCHOFF & ZIEGLER, 1957, Hess. Landesamt Bodenforsch., Abh., H. 22, p. 66, 130, pl. 21, fig. 23.

A single fragmented specimen is referred to this species. The cusp is heavy and curves sharply just above the base so that the distal portion is inclined posteriorly. A prominent longitudinal ridge along the anterolateral face of the cusp is a continuation of a row of denticles on the aboral process which is curved posteriorly beneath the posterior bar. Heavy denticles with circular cross sections are seated on the lateral face of the aboral process and curve orad and posteriorly immediately above their bases. Anterior margin of the aboral process is concave. The greater part of the posterior bar has been lost, and no denticles are remaining on it.

Remarks.—This species is previously known from the Saverton and Maple Mill in North America. Bischoff & Ziegler (1957)

reported it from Givetian and lower Frasnian strata in Germany.

Repository.—Figured hypotype, S.U.I. 10323.

Genus NEOPRIONIODUS Rhodes & Müller, 1956

Type species: *Prioniodus conjunctus* Gunnell, 1931.

NEOPRIONIODUS sp.
Pl. 90, fig. 10

The illustrated specimen has a blunt-edged cusp with convex lateral faces. The cusp is extended aborally as an anticusp whose anterior edge is turned slightly outward. The inner face of the cusp is broadly convex at the base. An inclined posterior bar forms an angle of approximately 45° with the anticusp and bears fused, laterally compressed denticles which stand erect parallel to the cusp. Suppression of a germ denticle between each pair of mature denticles is visible in outer lateral view. A conical basal cavity is confined to the base of the cusp and is not continued along the aboral edge of the posterior bar or the anticusp.

Remarks.—Another larger specimen belongs in this genus. It may represent a more mature growth stage of the illustrated form. The denticles have been broken, and the general outline is suggestive of *Neoprioniodus alatus* (Hinde).

Repository.—Figured specimen, S.U.I. 10324; unfigured specimen, S.U.I. 10325.

Genus OZARKODINA Branson & Mehl, 1933

Type species: *Ozarkodina typica* Branson & Mehl, 1933.

OZARKODINA REGULARIS Branson & Mehl

Ozarkodina regularis BRANSON & MEHL, 1934, Missouri Univ. Studies, v. 8, p. 287, pl. 23, figs. 13–14; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 138; KLAPPER, 1958, Jour. Paleontology, v. 32, p. 1087–1088, pl. 141, fig. 7.

Remarks.—Only a single specimen was recovered in the fauna from Cottonwood Canyon. It conforms closely to the specimens of *O. regularis* reported by Klapper from the Darby in which the species occurs in greater abundance.

Repository.—Unfigured hypotype, S.U.I. 10326.

Genus PALMATOLEPIS Ulrich & Bassler, 1926

Type species: *Palmatolepis perlobata* Ulrich & Bassler, 1926.

PALMATOLEPIS sp.

Remarks.—A single fragmented specimen is referred to this genus. The rather thin, translucent platform and low carina suggest that this is an immature specimen. The upper surface lacks ornamentation other than a prominent azygous node and sigmoidal carina; the lower surface has a sigmoidal keel. The unbroken outer lateral edge of the platform is regularly convex except for a shallow sinus near the posterior end. General configuration of the unit is suggestive of *Palmatolepis hassi* Müller & Müller. The specimen definitely belongs in the subgenus *Manticolepis* which, according to Müller & Müller (1957, p. 1081), appears to be restricted to early Upper Devonian.

Repository.—Unfigured specimen, S.U.I. 10327.

Genus PELEKYSGNATHUS Thomas, 1949

Type species: *P. inclinata* Thomas, 1949.

This genus was designated for a series of forms from the Upper Devonian Maple Mill Shale of southeastern Iowa. The type species represents an arched bar set with discrete denticles. A prominent cusp, reinterpreted to be anterior in position, is inclined at 45 degrees to the general alignment of the bar. The tapered broad shallow basal excavation and slight lateral flexure are characteristic of the genus. An associated species, *P. costata* Thomas, has cross ridges instead of laterally compressed denticles, also a less prominent but more strongly inclined cusp.

Hass (1959, p. 378–379) regarded *Pelekysgnathus* as a prioniodid, rather than an icriodid. However, the similar overall form and the variety of transitional species indicates that a closer relationship exists. Some advanced representatives of *Icriodus* show a moderately well developed cusp, and the basal cavity of the two genera is generally similar. Those species of *Pelekysgnathus*

with lateral denticles fused into cross ridges show a resemblance to the typical triserial oral surface of *Icriodus*.

Pelekysgnathus is apparently restricted to the Upper Devonian and may represent therefore a descendant of *Icriodus*, which characterizes older beds. Source beds of the type of *Pelekysgnathus* have been interpreted to be middle Upper Devonian "not younger than *Platyclymenia*-Stufe" (Müller & Müller, 1957, p. 1077).

PELEKYSGNATHUS DARBYENSIS (Klapper)
Pl. 90, figs. 12–17

Icriodus sp. BRANSON & MEHL, 1938, Jour. Paleontology, v. 12, p. 156; BRANSON & BRANSON, 1941, Am. Assoc. Petroleum Geologists, Bull., v. 25, p. 130; BLACKSTONE & MCGREW, 1954, Billings Geol. Soc., Guidebook 5th Ann. Field Conf., p. 39,42.

Icriodus darbyensis KLAPPER, 1958, Jour. Paleontology, v. 32, p. 1086, pl. 141, figs. 9,11,12.

Included in this species are thick massive units whose aboral profile is highly arched and whose oral edge is nearly straight. A large anterior cusp is inclined at 45° to the oral margin. Short, nodular denticles are arranged along the oral edge of the unit in three parallel rows of which the center row contains 5–7 denticles and the cusp. Each lateral row consists of three denticles which are partially fused to the adjacent denticle of the middle row to form a transverse ridge. Size of denticles increases anteriorly in the center row. The anterior denticle in this series is inclined parallel to and fused to the cusp throughout its length. The unit flares aborally with a shallow basal cavity beneath the cusp tapering posteriorly to a narrow groove beneath the remainder of the unit.

Remarks.—This species is placed in *Pelekysgnathus* because of the pronounced inclined cusp and the highly arched profile. In contrast, *Icriodus* is relatively straight and lacks a distinct cusp. The species differs from typical *Pelekysgnathus* in the presence of more than a simple row of denticles. However, Thomas (1949, p. 424) noted that several of the denticles of *P. costata* are transverse ridges, and some of the specimens available for comparison from the Maple Mill Formation (Peterson, 1947) show even closer resemblance to the Wyoming species. Another similar representation, *Pelekysgnathus* sp. "A" of Voges (1959, p. 268, 287–288) from the Lower Carboniferous *Pericyclus*-Stufe in the Sauerland is interpreted to be reworked.

As interpreted by us, *P. darbyensis* shows considerable variation; small specimens are believed to represent growth stages, however. The species is distinctly intermediate in some respects between the types of *Icriodus* and *Pelekysgnathus*. The evolutionary trend, from the former to the latter, appears to have involved progressive arching of the unit and reduction in the rows of denticles.

Repository.—Figured hypotypes, S.U.I. 10328, 10329, 10330, 10331.

Genus POLYGNATHUS Hinde, 1879

Type species: *Polygnathus dubius* Hinde, 1879.

POLYGNATHUS TRIANGULARIS
Branson & Mehl

Polygnathus triangularis BRANSON & MEHL, 1934, Univ. Missouri Studies, v. 8, p. 247, pl. 21, figs. 16,20; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 160; BISCHOFF, 1957, Hess. Landesamt Bodenforsch., Abh., H. 19, p. 13,44,63; KLAPPER, 1958, Jour. Paleontology, v. 32, p. 1090, pl. 142, fig. 9.

Remarks.—A single fragmentary specimen conforms to *Polygnathus triangularis* in general outline, strong transverse ridges, and having the carina slightly displaced to one side of the platform. The same species was reported by Klapper from the Darby of western Wyoming in which it is also one of the less abundant faunal elements.

Repository.—Unfigured hypotype, S.U.I. 10332.

POLYGNATHUS WYOMINGENSIS Klapper
Pl. 90, figs. 1–3

Polygnathus wyomingensis KLAPPER, 1958, Jour. Paleontology, v. 32, p. 1090–1091, pl. 142, figs. 5–8.

In oral view the platform is deeply concave transversely. The carina is high and narrow with a serrate crest. Denticles of the blade are closely crowded and set deeply into the oral edge. Aborally, a small escutcheon is located slightly posterior to the junction of the blade and platform. Posterior to the escutcheon, a sharp central keel extends to the tip of the unit. The keel becomes increasingly sharp posteriorly, and

the entire unit is curved aborally toward the posterior tip.

Remarks.—Transverse ridges are less prominent on the platform of these specimens than on the types from the Darby. Such ridges are represented only by undulations of the oral surface of the platform along the lateral margins and by somewhat serrate edges. This species ranks second in abundance in the Cottonwood Canyon fauna.

Repository.—Figured hypotype, S.U.I. 10333.

Genus SCOLOPODUS Pander, 1856

Type species: *Scolopodus sublaevis* Pander, 1856.

SCOLOPODUS? sp.

Simple, conical denticles which occur in moderate abundance in the fauna are tentatively placed here. All have circular or elliptical cross sections with no external ornamentation. The basal portion of these teeth flares slightly; the aboral margin is circular. A deep, asymmetrically conical cavity penetrates the unit from the base with the apex located near the convex side of the tooth. Considerable variation in longitudinal curvature occurs among the various specimens.

Remarks.—These forms are atypical of *Scolopodus* commonly an Ordovician form, which is defined as having costate lateral faces and elliptical cross section. Sannemann (1955, p. 154) has identified specimens transitional to *Acodina* from the Upper Devonian of the Frankenwald as *Scolopodus*. Derivation from the nondescript Ordovician forms is questionable.

Repository.—Unfigured specimens, S.U.I. 10334.

Genus SPATHOGNATHODUS Branson & Mehl, 1941

Type species: *Spathodus primus* Branson & Mehl, 1933.

This taxon has been studied in detail by several authors, but is still in a somewhat unsettled state. *Spathodus* Branson & Mehl [*non* Boulenger] was proposed for *S. primus* from the Silurian of Missouri. The genus was described and illustrated as a nearly straight blade with closely set vertical denticles and a basally expanded flange located at about midlength. Dozens of species from Silurian, Devonian, and Carboniferous strata were described before the original authors noted that the term was a homonym and proposed *Spathognathodus* as a substitute.

The close relationship of *Ctenognathodus* Fay 1959 [= *Ctenognathus* Pander, 1856, *non* Fairmaire, 1843] to *Spathognathodus* has been recognized by several authors (e.g., Müller & Müller, 1957, p. 1082). Gross (1954) had also reached the same conclusion after restudying abundant and well preserved *C. murchisoni*, the type species, from the original locality, Upper Silurian of the Esthonian island of Oesel (Lindström, 1959, p. 438). Earlier authors had questioned the adequacy of the original figures (Pander, 1856, pl. 4, fig. 17a), but Gross (*ibid.*, p. 75) regarded them as reliable for reference.

Fay's (1959, p. 195) substitution for a preempted name is not possible under the Rules, because a valid subjective synonym, *Spathognathodus*, is available (Hass, 1959, p. 378). Several related taxa should probably be recognized as subgenera: *Mehlina* Youngquist, 1945; *Pandorinellina* Hass, 1957 (*in* Müller & Müller); and possibly *Branmehla* Hass, 1959. All these designations are "parataxial," but *Lochriea* Scott, 1942, has been designated for an assemblage containing *Spathognathodus* and others.

Some representatives of *Spathognathodus* such as *S. aculeatus*, which occurs in the Devonian of Wyoming, differ from the type of the genus in possession of a few transverse, or offset, denticles. However, such species are associated normally with forms which lack this feature and are otherwise similar.

As now defined, *Spathognathodus* is extremely common in the Devonian and Carboniferous. The type is from the Silurian, and the genus is interpreted as occurring at least as early as the Middle Ordovician. In younger strata, it occurs as late as Lower Triassic.

SPATHOGNATHODUS ACULEATUS (Branson & Mehl)
Pl. 90, figs. 5–9

Spathodus aculeatus BRANSON & MEHL, 1934, Univ. Missouri Studies, v. 8, p. 186–187, pl. 17, figs. 11,14.

Spathognathodus aculeatus Branson & Mehl,

HASS, 1947, Jour. Paleontology, v. 21, p. 134, 135,140; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 186; GRAVES, 1952, Jour. Paleontology, v. 26, p. 612, pl. 81, figs. 1,3–5; HASS, 1956, U. S. Geol. Survey, Prof. Paper 286, p. 17,22,24; KLAPPER, 1958, Jour. Paleontology, v. 32, p. 1091, pl. 141, fig. 13; HELMS, 1959, Geologie, Jg. 8, H. 6, p. 657, pl. 3, fig. 8.

Included in this species are laterally compressed, elongate, high blades which are denticulate throughout their entire length. Broadly flaring lateral lips just posterior to midlength enclose a large aboral navel. The unit is highest at the anterior end; the oral edge is somewhat sinuous, being concave anteriorly and convex posteriorly. The single complete specimen bears 29 denticles. Posterior to and above the large aboral navel, the denticles are long and deeply set into the unit, extending almost to the aboral edge of the blade. Anterior to the navel, the denticles are short and do not penetrate into the blade. The four anteriormost denticles are somewhat longer than the others and not completely fused to their tips. At least three denticles are offset from the main series immediately above the navel and are larger than the other teeth. The offset denticles may be connected to those of the main row by transverse ridges or be discrete. Reduction in number of denticles is indicated by presence of unerupted denticles crowded between those of the main row immediately above the navel.

Remarks.—All but one of the specimens examined were broken, but sufficient fragments were recovered to indicate that this species is the most abundant in the fauna; it is equally common in the Darby of the Wind Rivers. In such abundance, at least, the species has considerable stratigraphic significance in the United States and Germany. Hass (1947, p. 134–135) reported *S. aculeatus* as abundant in Cleveland and upper Ohio shales in Ohio and later (1956, p. 17,22) regarded the species as an index for the uppermost Chattanooga Shale (Gassaway Member) in Tennessee; and Helms (1959) reported the same form from the *Clymenia*-Zone of Thuringia. However, several closely similar species (e.g., *S. tridentatus* E. R. Branson) have been reported from somewhat younger strata in North America and Europe.

Repository.—Figured hypotypes, S.U.I. 10335, 10336, 10337, 10338, 10339; unfigured hypotype, S.U.I. 10340.

REFERENCES

ANDRICHUK, J. M., 1951, Regional stratigraphic analysis of Devonian System in Wyoming, Montana, and southern Saskatchewan: Am. Assoc. Petroleum Geologists, Bull., v. 35, p. 2368–2408.

——, 1956, Devonian stratigraphy in northwestern Wyoming and adjoining areas: Wyoming Geol. Assoc., Guidebook, 11th Ann. Field Conf., p. 43–50.

BISCHOFF, GÜNTHER, 1956, Oberdevonische Conodonten (tolδ) aus dem Rheinischen Schiefergebirge: Hess. Landesamt Bodenforsch., Notizbl., Bd. 84, p. 115–137, pls. 8–10.

——, 1957, Die Conodonten-Stratigraphie des rhenohyrzynischen Unterkarbons mit Berücksichtigung der *Wocklumeria*-Stufe und der Devon Karbon-Grenze: *ibid.*, Abh., H. 19, 64 p., 6 pls.

—— & ZIEGLER, WILLI, 1956, Das Alter der "Urfer Schichten" im Marburger Hinterland nach Conodonten: *ibid.*, Notizbl., Bd. 84, p. 138–169, pls. 11–14.

—— & ——, 1957, Die Conodontenchronologie des Mitteldevons und des tiefsten Oberdevons: *ibid.*, Abh., H. 22, 136 p., 21 pls.

BLACKSTONE, D. L., JR. & MCGREW, P. O., 1954, New occurrence of Devonian rocks in north central Wyoming: Billings Geol. Soc., Guidebook, Fifth Ann. Field Conf., p. 38–43.

BLACKWELDER, ELIOT, 1918, New geological formations in western Wyoming: Washington Acad. Sci., Jour., v. 8, p. 417–426.

BRANSON, E. B. & MEHL, M. G., 1934, Conodonts from the Grassy Creek Shale of Missouri: Univ. Missouri Studies, v. 8, p. 171–259, pls. 13–21.

—— & ——, 1938, The conodont genus *Icriodus* and its stratigraphic distribution: Jour. Paleontology, v. 12, p. 156–166, pl. 26.

BRANSON, E. R., 1934, Conodonts from the Hannibal Formation of Missouri: Univ. Missouri Studies, v. 8, p. 301–334, pls. 25–28.

COLLINSON, C. W., REXROAD, C. B. & SCOTT, A. J., 1959, Abundance and stratigraphic distribution of Devonian and Mississippian conodonts in the Upper Mississippi Valley: Jour. Paleontology, v. 33, p. 692–696.

COOPER, C. L., 1945, Devonian conodonts from northwestern Montana: *ibid.*, v. 19, p. 612–615, pl. 84.

DORF, ERLING, 1934, Stratigraphy and paleontology of a new Devonian formation at Beartooth Butte, Wyoming: Jour. Geology, v. 42, p. 720–737.

FAY, R. O., 1952, Catalogue of condonts: Univ. Kansas Paleont. Contr., Vertebrata, art. 3, 206 p.

——, 1958, A key to conodont genera and subgenera: Okla. Geology Notes, v. 18, p. 103–120, 178.

———, 1959, Generic and subgeneric homonyms

of conodonts: Jour. Paleontology, v. 33, p. 195–196.

GRAVES, R. W., JR., 1952, Devonian conodonts from the Caballos Novaculite: *ibid.*, v. 26, p. 610–612, pls. 79–81.

GROSS, WALTER, 1954, Zur Conodonten-Frage: Senck. leth., Bd. 35, p. 73–85, 5 pls.

HASS, W. H., 1947, Conodont zones in Upper Devonian and Lower Mississippian formations of Ohio: Jour. Paleontology, v. 21, p. 131–141.

——, 1956, Age and correlation of the Chattanooga Shale and the Maury Formation: U. S. Geol. Survey, Prof. Paper 286, 47 p., 5 pls.

——, 1959, Conodonts from the Chappel Limestone of Texas: *ibid.*, Prof. Paper 294-J, p. 365–399, pls. 46–50.

HELMS, JOCHEN, 1959, Conodonten aus dem Saalfelder Oberdevon (Thüringen): Geologie, Jg. 8, H. 6, p. 634–677, pls. 1–6.

KLAPPER, GILBERT, 1958, An Upper Devonian conodont fauna from the Darby Formation of the Wind River Mountains, Wyoming: Jour. Paleontology, v. 32, p. 1082–1093, pls. 141–142.

LARIMER, T. R., 1959, Paleogeography of the Pre-Mississippian surface, Bighorn Mountains, Wyoming: State Univ. Iowa (Unpub. M.S. Thesis).

LINDSTRÖM, MAURITS, 1959, Conodonts from the Crug limestone (Ordovician, Wales): Micropaleontology, v. 5, p. 427–452, pls. 1–4.

MILLER, A. K., & YOUNGQUIST, W. L., 1947, Conodonts from the type section of the Sweetland Creek Shale in Iowa: Jour. Paleontology, v. 21, p. 501–517, pls. 72–75.

MILLS, N. A., 1956, Subsurface stratigraphy of the Pre-Niobrara formations in the Big Horn Basin, Wyoming: Wyoming Geol. Assoc., Wyoming Stratigraphy, Part 1, p. 9–22.

MÜLLER, K. J., 1956, Die Gattung *Palmatolepis:* Senck. Naturforsch. Gesellschaft, Abh., Bd., 494, 70 p., 11 pls.

—— & MÜLLER, E. M., 1957, Early Upper Devonian (Independence) conodonts from Iowa: Jour. Paleontology, v. 31, p. 1069–1108, pls. 135–142.

PEALE, A. C., 1893, The Paleozoic section in the vicinity of Three Forks, Montana: U. S. Geol. Survey, Bull. 110, 45 p., 6 pls.

PETERSON, R. F., 1947, Conodonts from the Maple Mill Formation of southeastern Iowa: State Univ. Iowa (Unpub. M.S. Thesis).

RICHARDS, P. W., 1955, Geology of the Bighorn Canyon-Hardin area, Montana and Wyoming: U. S. Geol. Survey, Bull. 1026, 93 p., 7 pls.

SANDBERG, C. A. & HAMMOND, C. R., 1958, Devonian System in Williston Basin and central Montana: Amer. Assoc. Petroleum Geologists, Bull., v. 42, p. 2293–2334.

SANNEMANN, DIETRICH, 1955a, Oberdevonische Conodonten (to IIα): Senck. leth., Bd. 36, p. 123–156, pls. 1–6.

——, 1955b, Beitrag zur Untergliederung des Oberdevons nach Conodonten: N. Jahrb. Geologie-Paläontologie, Abh., Bd. 100, p. 324–331, pl. 24.

SCHINDEWOLF, O. H., 1957, Suborder Clymeniina; *in* Arkell, *et al.*, Cephalopoda, Ammonoidea: Treatise Invert. Paleontology, Moore ed., Pt. L, Mollusca 4, p. 37–47.

SCOTT, A. J., 1958, Late Devonian and Early Mississippian conodont faunas of the Upper Mississippi Valley [abstract]: Dissertation Abstracts, v. 19, p. 1056–1057.

SLOSS, L. L. & LAIRD, W. M., 1947, Devonian System in central and northwestern Montana: Amer. Assoc. Petroleum Geologists, Bull., v. 31, p. 1404–1430.

THOMAS, L. A., 1949, Devonian-Mississippian formations of southeast Iowa: Geol. Soc. America, Bull., v. 60, p. 403–437, 4 pls.

TOMLINSON, C. W., 1917, The Middle Paleozoic stratigraphy of central Rocky Mountains region: Jour. Geology, v. 25, p. 112–134, 244–257, 373–394.

VOGES, ADOLF, 1959, Conodonten aus dem Untercarbon I und II (*Gattendorfia-* und *Pericyclus*-Stufe) des Sauerlandes: Paläont. Zeitschr., Bd. 33, p. 266–314, pls. 33–35.

WILSON, J. L., 1956, Stratigraphic position of the Upper Devonian branchiopod *Rhabdostichus* in the Williston Basin: Jour. Paleontology, v. 30, p. 959–965.

WINGERT, J. R., 1958, Geology of the Bald Mountain area, Bighorn Mountains, Wyoming: State Univ. Iowa (Unpub. M.S. Thesis).

YOUNGQUIST, W. L., 1947, A new Upper Devonian conodont fauna from Iowa: Jour. Paleontology, v. 21, p. 95–112, pls. 24–26.

—— & PETERSON, R. F., 1947, Conodonts from the Sheffield Formation of north-central Iowa: *ibid.*, p. 242–253, pls. 36–38.

JOURNAL OF PALEONTOLOGY, V. 35, NO. 4, P. 769–788, PLS. 91–93, 2 TEXT-FIGS., JULY, 1961

JACKSON EOCENE OSTRACODA FROM THE COCOA SAND OF ALABAMA

PAUL R. KRUTAK
Louisiana State University, Baton Rouge

ABSTRACT—This paper deals with a taxonomic study of the Ostracoda from a portion of the lower Jackson Eocene sequence (Cocoa Sand) in Choctaw County, Alabama. Thirty-four species are figured and described. Eleven of the thirty four are described as new; they include *Cytherelloidea cocoaensis, Loxoconcha concentrica, Loxoconcha watervalleyensis, Loxoconcha cocoaensis, Cushmanidea keyserensis, Cushmanidea papula, Cushmanidea serangodes, Acuticythereis cocoaensis, Cytheromorpha calva, Triginglymus gnythophoreus,* and *Absonocytheropteron watervalleyensis. Konarocythere,* nom. nov., is proposed for *Budaia* Mehes, 1941, preoccupied.

HISTORICAL RECAPITULATION

IN December, 1914, C. Wythe Cooke made a series of collections from strata in Alabama, among them being a bed to which he applied the field name Cocoa Sand. Although he did not intend to publish this name, and did not use it in the "Geology of Alabama" or other papers, the name Cocoa Sand was later incorporated into the literature.

In 1925, J. A. Cushman published a paper entitled "Eocene Foraminifera from the Cocoa Sand of Alabama." This paper was based on specimens taken from the samples collected by Cooke, which were sent to Cushman by the United States National Museum. Cushman no doubt used the formation name that he found on the field labels. Previous to this the name Cocoa Sand apparently had never been published. Cushman failed to designate a type section, merely mentioning that it is of Upper Eocene (Jackson) age, and that it occurs at Cocoa Post Office, Alabama. Later papers by Cushman (1928) (1946), dealing with Foraminifera from the so-called "Cocoa Sand" of Alabama were published; however, the fauna described in these three papers appears to have come from clays above the Cocoa Sand (*fide* Howe, 1947b).

Several years later Cooke formally designated a type section. According to Cooke (1933) the name is taken from the abandoned country post office called Cocoa that many years ago stood in the SW ¼ of Sec. 13, T.11 N., R.5 W., Choctaw County, Alabama, about 2.5 miles east of Melvin, Alabama on the road to Gilbertown. Cooke's section, taken ½ mile southwest of Cocoa, Alabama, is given below:

(Oligocene: Vicksburg Group: Red Bluff clay)

4. Concealed. Exposures elsewhere in vicinity show that above bed 3 is yellowish brown argillaceous marl containing *Spondylus dumosus* and *Ostrea vicksburgensis,* overlain by gray-to-yellow clay with crystals of gypsum and many Red Bluff fossils.

(Eocene: Jackson Formation)

3. Drab clay containing irregular calcareous concretions in lower part. About ..... 10′
2. *Zeuglodon*-bearing bed. Gray or drab sandy and argillaceous marl with harder ledges and irregular calcareous concretions; very argillaceous in upper part; about ..... 11′
1. (Cocoa Sand member) Fine yellow sand with soft white calcareous lumps and large irregular lumps of hard yellow sandy marl. Grades upward into bed 2 ..... 6′

The Cocoa Sand's stratigraphic position is shown below in Cooke's generalized section of the Jackson Formation in Choctaw County, Alabama, which was adapted from his "Geology of Alabama."

5. Calcareous clay ..... 25′
4. *Zeuglodon*-bearing bed; yellowish or grayish marl with ledges; *Ostrea trigonalis, Ostrea falco, Schizaster armiger, Pecten spillmani, Zeuglodon,* and other fossils ..... 11′–15′
3. Cocoa Sand member. Fine yellow sand, partly calcareous and argillaceous, with shells in lower part ..... 17′–70′
2. Light green plastic calcareous clay with shells; in part micaceous and sandy ..... 30′–50′

1. *Periarchus*-bearing bed (*Scutella* bed of previous papers). Ledges of gray indurated marl; *Pecten spillmani, Periarchus pileussinensis*, and other fossils..... 1'–10'

G. E. Murray (1947) discussed the Jackson Group (Eocene) and subdivided it into four lithologic units. The names were proposed for surface units which were later projected into the subsurface by use of well information. The following data were compiled from Murray's footnote on p. 1839:

Shubuta (clay) Member—proposed for 20–250 feet of clays and clayey marls, underlain by the Pachuta Marl and overlain by the Forest Hill Sand or Red Bluff Clay of the Oligocene.
Type Locality.—Exposures on the east side of the Chickasawhay River, just north of the old U.S. Highway 45 bridge east of Shubuta, Clarke County, Mississippi (SW ¼ of Sec. 3, T. 10 N., R. 16 E.).

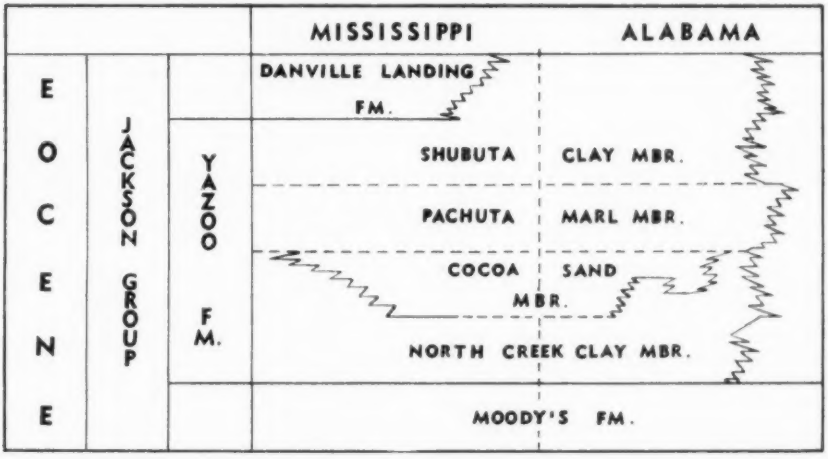
Pachuta (marl) Member—proposed for 6–25 feet of buff, gray, or white, partially indurated, generally glauconitic, fossiliferous marl, overlain by the Shubuta Clay and underlain by the Cocoa Sand or North Creek Clay. This is the *Zeuglodon* or *Pecten-Bryozoa* bed of previous workers.
Type Locality.—Exposures on the south side of Pachuta Creek, 1¼ miles south and southeast of Pachuta in the SW ¼ of Sec. 8, T. 2 N., R. 14 E., Clarke County, Mississippi.

North Creek (clay) Member—proposed for an average of 40 feet of green or gray, slightly glauconitic, fossiliferous clay, underlain by the Moody's Sand and overlain by the Pachuta Marl or the Cocoa Sand.
Type Locality.—Exposures on the west side of North Creek in the SW ¼ of Sec. 1, T. 3 N., R. 12 E., Jasper County, Mississippi, 2 miles southwest of Rose Hill on the graveled state highway to Gridley and Turnersville.

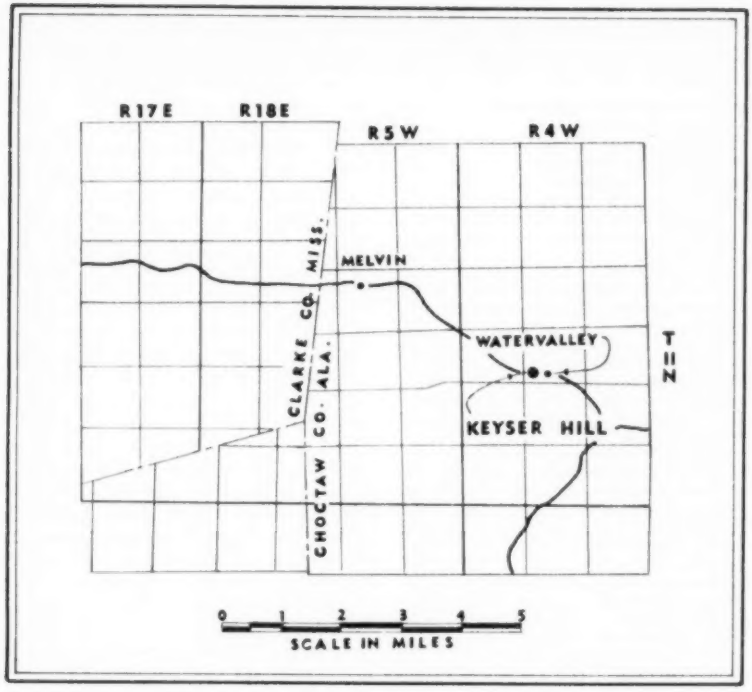
A diagrammatic composite outcrop section Text-fig. (1) taken from Fig. 6 of Murray's 1947 paper illustrates the stratigraphic position of the Cocoa Sand.

Comparing Murray's section with Cooke's generalized section of the Jackson Formation in Choctaw County, Alabama, it is evident that: Bed No. 1 is Murray's Moody's Formation; Bed No. 2 equals Murray's North Creek Clay; Bed No. 3 is the Cocoa Sand; Bed No. 4 is synonymous with the Pachuta, and Bed No. 5 is a part of the Shubuta Clay of Murray.

In 1947 a field party from the Chicago Natural History Museum visited the type area of the Cocoa Sand and on discovering that the post office which Cooke referred to no longer existed, suggested that the home of Mr. A. L. Pippen be used as a marker. The house is located across the road (south) from the old Cocoa Post Office site.



TEXT-FIG. 1—Diagrammatic composite outcrop section illustrating the stratigraphic position of the Cocoa Sand. From Murray, 1947, fig. 6.



TEXT-FIG. 2—Location Map. After Blanpied *et al.*, 1394.

SAMPLED SECTION

A well exposed section of the Cocoa Sand crops out in Choctaw County, Alabama about ¼ mile west of Water Valley on "Slick" or Keyser Hill (Cooke 1926, pp. 274,275). The exposed section, which is near the southwest corner of Sec. 20, T.11 N., R.4 W. (Text-fig. 2), has thickened from that of the type locality, being about 20 feet thick.

Samples were taken at five-foot intervals starting at a point 51 feet (by hand level) above the bridge near Water Valley (which is 3.7 miles southeast of Melvin, Alabama, on the road to Gilbertown). The basal sample is from a position west of the bridge. Five samples, encompassing 20 feet of section, were taken, which all contain an abundant ostracode fauna. The lithology of the sampled interval, as determined under the binocular microscope, is as follows:

Sample No. 5—(71′ above bridge near Water Valley). Sandstone; bluish gray, fine-grained, soft, quartzose, angular, with clay cement, highly fossiliferous, trace of glauconite.
Sample No. 4—(66′ above bridge near Water Valley). Sandstone; as above.
Sample No. 3—(61′ above bridge near Water Valley). Sandstone; as above.
Sample No. 2—(56′ above bridge near Water Valley). Sandstone; as above.
Sample No. 1—(51′ above bridge near Water Valley). Sandstone; yellow-orange, fine-grained, soft, quartzose, angular, with clay cement, highly fossiliferous, limonitic.

FAUNAL DISTRIBUTION

The ostracode fauna herein described remains essentially constant throughout the sampled interval, though a few of the rarer species are present only in certain samples. A range chart for this sampled interval has been prepared which shows the distribution of the species within the sampled interval (Table 1).

TABLE 1—RANGE CHART

Name of Species	Sample Number				
	1	2	3	4	5
Absonocytheropteron watervalleyensis	×	—	—	×	×
Actinocythereis gibsonensis	×	×	×	×	×
Acuticythereis cocoaensis	×	×	×	×	×
"Archicythereis" yazooensis	×	×	×	×	×
Brachycythere mississippiensis	—	×	—	×	—
Brachycythere watervalleyensis	×	×	×	×	×
Buntonia shubutaensis	×	×	×	×	×
Clithrocytheridea caldwellensis	—	×	×	×	×
Clithrocytheridea garretti	×	×	×	×	×
Clithrocytheridea grigsbyi	×	×	×	×	×
Clithrocytheridea shubutensis	×	×	×	×	×
Cushmanidea keyserensis	×	×	×	×	×
Cushmanidea papula	×	×	×	×	×
Cushmanidea serangodes	×	×	—	×	×
Cyamocytheridea watervalleyensis	×	×	×	×	×
Cytherelloidea montgomeryensis	×	—	—	—	—
Cytherelloidea cocoaensis	—	×	×	×	×
Cytheretta alexanderi	×	×	×	×	×
Cytheromorpha calva	×	×	×	—	—
Cytheropteron montgomeryensis	×	×	×	×	×
Echinocythereis jacksonensis	×	×	×	—	—
Haplocytheridea montgomeryensis	×	×	×	×	×
Henryhowella florienensis	×	×	×	×	×
Hermanites (?) dohmi	×	×	×	—	×
Hermanites (?) hysonensis	×	—	×	×	×
Konarocythere spurgeonae	×	×	×	×	×
Loxoconcha cocoaensis	×	×	×	—	—
Loxoconcha concentrica	×	×	—	—	—
Loxoconcha creolensis	×	—	—	—	×
Loxoconcha jacksonensis	×	—	×	×	—
Loxoconcha watervalleyensis	×	—	—	—	—
Paracypris franquesi	×	—	×	—	—
Trachyleberis montgomeryensis	×	×	×	×	×
Triginglymus gnythophoreus	×	×	×	×	×

ACKNOWLEDGMENTS

The writer wishes to express his thanks to H. V. Howe, director of the School of Geology, Louisiana State University, for his invaluable assistance and guidance, and is indebted to W. A. van den Bold, professor of geology, Louisiana State University, for his kind help in translating one of the Russian publications. Grover E. Murray, Boyd professor of geology, Louisiana State University, assisted and guided the writer during the collecting of samples, as did Lewis G. Nichols, assistant curator, Louisiana State University Geology Museum. Thanks are also due fellow graduate students Orlando Brown, Otto Buis, and Charles Jones, who all assisted in the hand-leveling and collecting of samples.

The type numbers refer to the H.V. Howe collection, Louisiana State University, Baton Rouge, Louisiana. All figures and plates were drawn by the writer.

SYSTEMATIC DESCRIPTIONS

Order OSTRACODA Latreille, 1806

Suborder PLATYCOPA Sars, 1866

Family CYTHERELLIDAE Sars, 1866

Genus CYTHERELLOIDEA Alexander, 1929

CYTHERELLOIDEA MONTGOMERYENSIS Howe, 1934

Pl. 93, figs. 7 (female), 10 (male)

Cytherelloidea montgomeryensis HOWE, 1934; Jour. Paleontology, v. 8, no. 1, p. 29–34, pl. 5; —— & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 7,8, pl. 5, fig. 4; GARRETT, 1936, Jour. Paleontology, v. 10, no. 8, p. 786; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 94; SEXTON, 1951, Jour. Paleontology, v. 25, no. 6, p. 808,810, pl. 115, fig. 21.

Cytherelloidea danvillensis WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 125, pl. 1, fig. 17.

Diagnosis.—A species of *Cytherelloidea* characterized by two median rims; in females the ventral rim is essentially straight; the dorsal rim is curved down and around a depression which develops just above the center of the valve, and it dies out before it reaches the anterior or dorsum. Male valves are distinguished by the two median ribs which fail to connect to either anterior or posterior margins, dying out about equidistant from either end.

Remarks.—This species shows marked sexual dimorphism. In female carapaces the posterodorsal and posteroventral portions of the valves are swollen, forming two circular pits on the inside and two raised nodes on the exterior. Male valves are much shallower, and lack the two circular posterior pits. The hinge is a modification of the peripheral lock, consisting of an upraised portion of the hingement in the left valve just behind the central depressed area which forms a raised flange that fits into a corresponding depression in the right valve.

In Howe & Chambers (1935), mention is made of the male of this species under the description of *C. danvillensis* (p. 7), wherein it is stated that a variety of *C. danvillensis*, differing from *C. danvillensis* "in not having a low rounded semicircular ridge above the pit" is common in nearly all marine lower Jackson localities. This variety is actually the male of *C. montgomeryensis*. The description in Howe & Chambers (1935) is that of a left valve of a female. The right valve of the female differs slightly, being larger and lacking the depressed area anterior to the center of the dorsal margin.

Muscle scars are located slightly above the middle of the carapace on a raised area which corresponds with the external depression. They consist of two closely adjacent rows arranged vertically; the front row consisting of seven scars, the top four long, thin, and longitudinally elongate, the third from the bottom much shorter, the bottom two very tiny and situated slightly posterior to the other five. The back row consists of eight scars, the top two similar to the ones in the front row. Two smaller scars lie immediately below this; subjacent to these is another elongate scar, which is bounded ventrally by two smaller scars. A single elongate scar sits astride the top of the two rows.

Figured Specimens.—Plesiotype No. 5850, a female left valve from sample No. 1: length, 0.58 mm.; height, 0.34 mm. Plesiotype No. 5851, a male left valve from sample No. 1: length, 0.54 mm.; height, 0.30 mm.

CYTHERELLOIDEA COCOAENSIS
Krutak, n. sp.
Pl. 93, fig. 13

Diagnosis.—A species of *Cytherelloidea* characterized by a low raised rim which begins at the posterodorsal angle, extends forward and down, meeting a rim which is a vertical extension of the median rim at an obtuse angle just above and anterior to the center of the carapace.

Description.—Carapace in side view oblong; right valve larger, the left valve being overlapped on all sides. Dorsal margin of left valve depressed anterior to center; dorsal margin of right essentially straight, paralleling the ventral margin. Ventral margin nearly straight. Anterior end evenly and broadly rounded; posterior end truncate; elevated.

External ornamentation consists of a low marginal rim which begins at the posterodorsal angle, extends along the dorsal, anterior, and ventral margins, and ends at the posteroventral angle. The rim is highest and most prominent around the anterior end. A depression develops just above the middle of the valve, extends up to a downwardly inclined rim, follows it posteriorly where it narrows and dies out at the posterior cardinal angle. A raised rim begins on the posterior end above the middle of the carapace; extends forward and obliquely downward, paralleling the ventral edge of the depression, and in immature specimens fades out toward the anterior before it reaches the anterior marginal rim. Mature specimens possess a median rim that turns sharply upward at nearly a right angle on the anteroventral side of the median depression, and continues toward the dorsum up to a point posterior to the center of the dorsal margin. The right valve exhibits this dorsal rim best. A ventral rim, starting at the posterior below the middle of the valve, continues forward almost as a straight line, dying out before it reaches the anterior rim.

A modified peripheral lock holds the two valves together. A deep elongate depression

develops just behind the centrodorsal margin on the inside of the right valve. It shallows anteriorly and posteriorly. An upraised flange just behind the centrodorsal depression of the left valve fits into the depression in the right.

Remarks.—This species is close to *C. montgomeryensis* Howe, but is set apart by the dorsal rim that develops above the central depressed area. The writer found no male carapaces, although they must exist unless the species is parthenogenetic. The new species is based on thirty-seven single valves and one whole carapace.

Figured Specimen.—Holotype No. 5852, a complete female carapace from sample No. 2: length, 0.60 mm.; height, 0.34 mm.; width, 0.22 mm.

Unfigured Specimens.—Paratype Nos. 5853, 5854.

Suborder PODOCOPA Sars, 1866
Family CYPRIDAE Baird, 1845
Subfamily CYPRINAE G. W. Muller, 1894
Genus PARACYPRIS Sars, 1866
PARACYPRIS FRANQUESI Howe & Chambers, 1935
Pl. 92, fig. 1

Paracypris franquesi HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 10, pl. 3, fig. 13, pl. 4, figs. 15,19; GARRETT, 1936, Jour. Paleontology, v. 10, no. 8, p. 786; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 89; BOLD, 1946, Contr. to the study of Ostracoda with special reference to the Tertiary and Cretaceous microfauna of the Caribbean region, p. 66, pl. 1, fig. 16; STEPHENSON, 1946, Jour. Paleontology, v. 13, no. 6, p. 309, pl. 42, fig. 4, pl. 44, fig. 11; BOLD, 1950, Jour. Paleontology, v. 24, no. 1, p. 108.
Paracypris strecca SCHMIDT, 1948, Jour. Paleontology, v. 22, no. 4, p. 408, pl. 63, figs. 21,22.
Paracypris cf. *P. franquesi* SWAIN, 1951, USGS Prof. Paper 234-A, p. 16, pl. 1, fig. 6.

Diagnosis.—This species of *Paracypris* is recognized by the sharp arching of the dorsal margin at the anterior cardinal angle; a hinge in which the groove lies in the left valve; comparatively large vestibules, and straight radial pore canals.

Remarks.—*P. rosefieldensis* Howe & Law of the Vicksburg Oligocene is the most closely related species. According to Howe & Law (1936) it differs from *P. franquesi* in having a more arched dorsal margin, reversed hingement, in which the groove lies in the right valve instead of the left, having its greatest height farther removed from the anterior end, smaller vestibules, and longer radial pore canals that tend to branch.

Figured Specimen.—Plesiotype No. 5855, a left valve from sample No. 1: length, 0.84 mm.; height, 0.32 mm.

Unfigured Specimen.—Plesiotype No. 5856.

Family CYTHERIDAE Baird, 1850
Subfamily LOXOCONCHINAE Sars, 1925
Genus LOXOCONCHA Sars, 1866
LOXOCONCHA COCOAENSIS Krutak, n. sp.
Pl. 93, fig. 2

Diagnosis.—A species of the genus *Loxoconcha* having a bladelike ridge dorsally and another thin curved ridge ventrally and ornamented with coarse pits and furrows that are arranged more or less longitudinally.

Description.—In dorsal view elongate-ovate with pointed ends; in side view elongate-ovate; translucent. Greatest length along midline. Dorsal and ventral margins essentially parallel, both partially obscured by raised, bladelike ridges. Anterior and posterior ends broadly rounded, the posterior slightly more sharply. A small glassy eyespot occurs below the anterior cardinal angle.

On the inside, the valves are rather shallow, and transparent, the exterior pits and punctations showing through the carapace. A weakly developed vestibule is evident anteriorly; about seven radial pore canals can be seen; three others are visible posteriorly. In the right valve, a selvage and flange groove are present along the ventral margin.

Muscle scars consist of a curved row of four adductors; two mandibulars, the upper opposite the lower adductor of the curved row, and a single oval antennal scar opposite the top adductor. The hinge is gongylodont.

Remarks.—This species is based on nineteen single valves. It appears to be most closely related to *L. watervalleyensis* Krutak from this same locale, but differs from it in its lateral outline, being more elongate, and surface ornamentation, being coarsely pitted.

Figured Specimen.—Holotype No. 5864, a right valve from sample No. 1: length, 0.42 mm.; height, 0.24 mm.

Unfigured Specimens.—Paratype Nos. 5865, 5866.

LOXOCONCHA CONCENTRICA Krutak, n. sp.
Pl. 93, fig. 6

Diagnosis.—This species of *Loxoconcha* is characterized by its coarsely pitted surface, the pits tending to be concentrically arranged.

Description.—Carapace in side view ovate. Dorsal margin essentially straight along hinge line, ventral margin curved slightly downward in centroventral region of left valve; essentially straight and subparallel to dorsal margin in right. Anterior end broadly rounded, posterior end more sharply rounded.

Internally, the valves are moderately deep and transparent. Marginal areas are widest around the anterior and posterior ends where small vestibules are developed. A few widely spaced, straight, radial pore canals occur at either extremity. In the right valve, a selvage and flange groove are developed along the ventral margin. The hinge is gongylodont.

Remarks.—*L. jacksonensis* Howe & Chambers, another Jackson Eocene form, appears to be the most closely related species. This species differs from the aforementioned in having concentrically arranged coarse pits, and a less ovate and slightly smaller carapace. The new species is based on sixteen single valves.

The specific name is derived from the medieval Latin word *concentricus*, meaning having a common center.

Figured Specimen.—Holotype No. 5861, a right valve from sample No. 1: length, 0.42 mm.; height, 0.24 mm.

Unfigured Specimens.—Paratype Nos. 5862, 5863.

LOXOCONCHA CREOLENSIS Howe & Chambers, 1935
Pl. 93, fig. 1

Loxoconcha creolensis HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 40,41, pl. 5, fig. 13; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 90,95; WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 125.
Loxoconcha cf. *L. creolensis* SWAIN, 1948, Maryland Board of Natural Resources, Cretaceous and Tertiary Subsurface Geology, p. 194, pl. 12, fig. 13; ——, 1951, USGS Prof. Paper 234-A, p. 27, pl. 2, fig. 15.

Diagnosis.—A very plump, ovate species of *Loxoconcha* ornamented by rather coarse pits arranged in longitudinal rows.

Remarks.—Viewed from the inside, the valves are very deep and transparent, the outer pits being visible from the inside. Marginal areas of essentially equal width are developed around the margin of the valves; a very narrow vestibule is present anteriorly. The hinge is strong gongylodont.

Figured Specimen.—Plesiotype No. 5857, a left valve from sample No. 1: length, 0.40 mm.; height, 0.26 mm.

Unfigured Specimen.—Plesiotype No. 5858.

LOXOCONCHA JACKSONENSIS Howe & Chambers, 1935
Pl. 93, fig. 9

Loxoconcha jacksonensis HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 41,42, pl. 4, fig. 20, pl. 5, fig. 14, pl. 6, figs. 8,9; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 90; BERQUIST, 1942, Miss. State Geol. Survey, Geol. Bull. 49, p. 109, pl. 11, fig. 18; WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 125.

Diagnosis.—A species of *Loxoconcha* set apart by its very minutely pitted carapace, the pits having no definite arrangement.

Remarks.—Muscle scars, located slightly anterior to the center of the carapace, consist of five adductors in a slightly curved row, the second from the top being a double scar. Three antennal scars in a staggered row lie above the adductors; a single curved mandibular scar appears to lie opposite the top two adductors.

Loxoconcha concentrica Krutak from this same horizon is the most closely related species; however, its surface is ornamented with coarse, concentrically arranged pits and it is less ovate and slightly smaller.

Figured Specimen.—Plesiotype No. 5859, a right valve from sample No. 1: length, 0.46 mm.; height, 0.24 mm.

Unfigured Specimen.—Plesiotype No. 5860.

LOXOCONCHA WATERVALLEYENSIS Krutak, n. sp.
Pl. 93, fig. 3

Diagnosis.—A species of the genus *Loxoconcha* having a bladelike ridge dorsally and a thin carinate ridge ventrally, and whose carapace is essentially smooth.

Description.—Ends rounded, dorsal and

ventral margins obscured by raised ridges in lateral view.

Surface of carapace essentially smooth, although some specimens show extremely faint reticulations around the anterior, and in the centroventral area may show a few pits.

Viewed from the inside, the valves are moderately deep. Marginal areas widest at ends with small vestibules and widely spaced, straight radial pore canals, about ten being present around the anterior and a few at the posterior. The hinge is gongylodont.

Remarks.—The closest relative to this species appears to be *L. cocoaensis* Krutak from this same horizon. This species differs from the aforementioned by being essentially smooth; and in lateral outline, being relatively much higher and more ovate. The new species is based on eight single valves and one whole carapace.

Figured Specimen.—Holotype No. 5867, a right valve from sample No. 1: length, 0.40 mm.; height, 0.24 mm.

Unfigured Specimens.—Paratype Nos. 5868, 5869.

Subfamily CYTHERURINAE
G. W. Muller, 1894
Genus KONAROCYTHERE (Mehes), 1941, nom. nov.
KONAROCYTHERE SPURGEONAE (Howe & Chambers), 1935
Pl. 92, fig. 4

Eocytheropteron spurgeonae HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 20,21, pl. 3, fig. 18, pl. 4, fig. 2, pl. 6, figs. 12,13; GARRETT, 1936, Jour. Paleontology, v. 10, no. 8, p. 786; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 89,93.

Diagnosis.—A species which has a nearly smooth exterior surface which is marked only by the orifices of normal pore canals and by smaller pitting in the areas between the canals.

Remarks.—Muscle scars consist of four adductors in a vertical row, in front of which are three additional scars; below the vertical row in the swollen portion of the carapace are two mandibular scars; in addition there are four other scars lying between the adductors and the hingement. Males of the species are generally larger, being more elongate and slightly higher than the females.

This species is most closely related to *K. fiski* (Howe & Law) of the Vicksburg Oligocene and is separated from it by its surface ornamentation, *K. fiski* having a coarsely reticulate carapace.

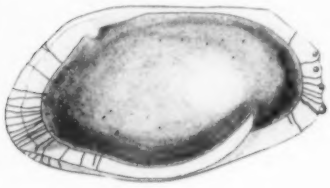
The name *Budaia* was applied to a lower Cretaceous trochosmiliid coral by Wells in 1933; therefore the name *Budaia* as applied by Mehes in 1941 to this genus is invalid. The new generic name is from the Greek κοναρός, meaning fat, or well fed, plus the ending -cythere.

Figured Specimen.—Plesiotype No. 5870, a female right valve from sample No. 1: length, 0.60 mm.; height, 0.32 mm.

Unfigured Specimens.—Plesiotype Nos. 5871, 5872.

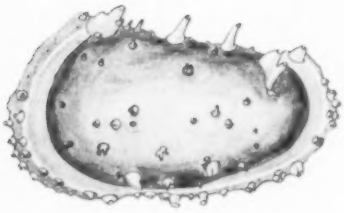
EXPLANATION OF PLATE 91

FIG. *1*—*Brachycythere watervalleyensis* Howe & Chambers. Female left valve, ×75. Plesiotype No. 5901.
2—*Cyamocytheridea watervalleyensis* (Stephenson). Right valve, ×75. Plesiotype No. 5882.
3—*Trachyleberis montgomeryensis* (Howe & Chambers). Left valve, ×75. Plesiotype No. 5914.
4—*Actinocythereis gibsonensis* (Howe & Chambers). Male right valve, ×75. Plesiotype No. 5904.
5–6—*Cytheretta alexanderi* Howe & Chambers. *5*, left valve, ×73, plesiotype No. 5919. *6*, right valve, ×75, plesiotype No. 5920.
7—*Haplocytheridea montgomeryensis* (Howe & Chambers). Left valve view of a complete female carapace, ×75. Plesiotype No. 5884.
8—*Henryhowella florienensis* (Howe & Chambers). Right valve view of a complete carapace, ×75. Plesiotype No. 5913.
9—*Echinocythereis jacksonensis* (Howe & Pyeatt). Left valve, ×75. Plesiotype No. 5911.
10—*Brachycythere mississippiensis* (Meyer). Male right valve, ×75. Plesiotype No. 5899.

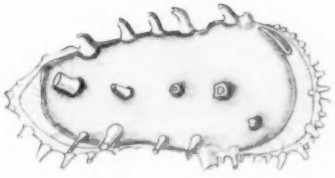


1

2



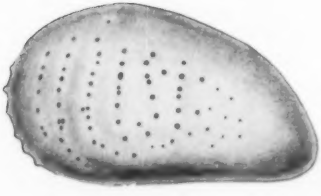
3



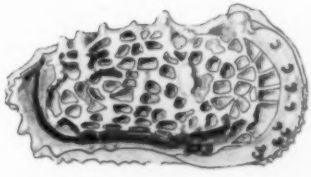
4

5

6



7

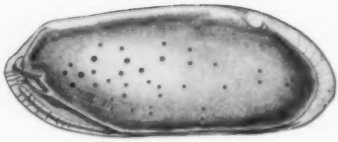


8

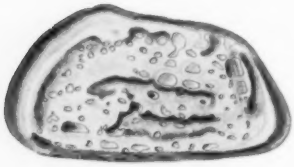
9

10

1

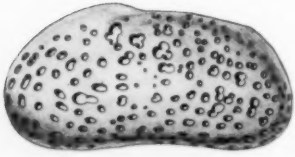


2



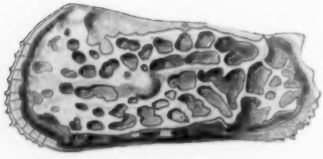
3

4

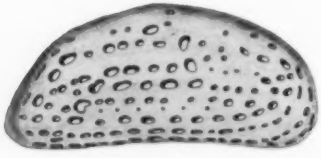


5

6



7



8

9

10

11

12

Genus CYTHEROPTERON Sars, 1865
CYTHEROPTERON MONTGOMERYENSIS
Howe & Chambers, 1935
Pl. 93, fig. 12

Cytheropteron montgomeryensis HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 19, pl. 3, figs. 14–16, pl. 4, figs. 11,12,16; GARRETT, 1936, Jour. Paleontology, v. 10, no. 8, p. 786; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 89; BERQUIST, 1942, Miss. State Geol. Survey, Geol. Bull. 49, p. 106, pl. 11, fig. 6; BOLD, 1946, Contr. to the study of Ostracoda with special reference to the Tertiary and Cretaceous microfauna of the Caribbean region, p. 114, pl. 2, fig. 12; ——, 1950, Jour. Paleontology, v. 24, no. 1, p. 108; WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 125.

Diagnosis.—This species of *Cytheropteron* is characterized by a number of vertical rows of very small, round pits on the posterior half of the carapace, and strongly produced alae which bear small spines on their back slopes.

Figured Specimen.—Plesiotype No. 5873, a right valve from sample No. 2: length, 0.46 mm.; height, 0.28 mm.

Unfigured Specimen.—Plesiotype No. 5874.

Subfamily CYTHERIDEINAE Sars, 1925
Genus CLITHROCYTHERIDEA
Stephenson, 1936
CLITHROCYTHERIDEA CALDWELLENSIS
(Howe & Chambers), 1935
Pl. 92, fig. 3

Cytheridea (?) *caldwellensis* HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 11, pl. 1, fig. 7, pl. 2, figs. 4–6.
Cytheridea caldwellensis GARRETT, 1936, Jour. Paleontology, v. 10, no. 8, p. 786.
Cytheridea (*Cleithrocytheridea*) *caldwellensis* [*sic*] MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, pp. 89,93.
Cytheridea (*Clithrocytheridea*) *caldwellensis* STEPHENSON, 1937, Jour. Paleontology, v. 11, no. 2, p. 154, pl. 26, fig. 13.
Clithrocytheridea caldwellensis STEPHENSON, 1946, Jour. Paleontology, v. 20, no. 4, p. 327, pl. 42, fig. 13; BLAKE, 1950, Jour. Paleontology, v. 24, no. 2, p. 175, pl. 29, fig. 12; HOWE, 1951, Fla. Geol. Survey, Geol. Bull. 34, p. 6.
Clithrocytheridea cf. *C. caldwellensis* SWAIN, 1951, USGS Prof. Paper 234-A, p. 24, pl. 2, fig. 28.
Cleithrocytheridea [*sic*] *caldwellensis* WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 125.

Diagnosis.—A strongly sexually dimorphous species of *Clithrocytheridea* characterized by a low anterior rim some distance in from the anterior margin; by a low weak muscle node behind which is an irregularly raised median rim, below which is a low ventral rim; and by coarse pits of varying outline.

Remarks.—The species resembles *C. saggitaria* Howe from the Avon Park Limestone, but is set apart by the much coarser surface pitting. Sexual dimorphism is well developed, the males being much longer than the females and not as high or as tumid.

Figured Specimen.—Plesiotype No. 5875, a female left valve from sample No. 4: length, 0.62 mm.; height, 0.34 mm.

Unfigured Specimen.—Plesiotype No. 5876.

EXPLANATION OF PLATE 92

FIG. *1*—*Paracypris franquesi* Howe & Chambers. Left valve, ×75. Plesiotype No. 5855.
2—*Acuticythereis cocoaensis* Krutak, n. sp. Male right valve, ×75. Holotype No. 5892.
3—*Clithrocytheridea caldwellensis* (Howe & Chambers). Female left valve, ×75. Plesiotype No. 5875.
4—*Konarocythere spurgeonae* (Howe & Chambers). Female right valve, ×75. Plesiotype No. 5870.
5—*Clithrocytheridea shubutensis* (Stephenson). Female left valve, ×75. Plesiotype No. 5880.
6—*Cushmanidea keyserensis* Krutak, n. sp. Right valve view of a complete carapace, ×75. Holotype No. 5885.
7—*Hermanites* (?) *hysonensis* (Howe & Chambers). Left valve, ×75. Plesiotype No. 5924.
8—*Clithrocytheridea garretti* (Howe & Chambers). Male right valve, ×75. Plesiotype No. 5877.
9—*Cushmanidea papula* Krutak, n. sp. Left valve, ×75. Holotype No. 5886.
10—*Cushmanidea serangodes* Krutak, n. sp. Male right valve, ×75. Holotype No. 5889.
11—*Absonocytheropteron watervalleyensis* Krutak, n. sp. Left valve view of a complete male carapace, ×75. Holotype No. 5921.
12—*Clithrocytheridea grigsbyi* (Howe & Chambers). Right valve views of a complete male carapace, ×75. Plesiotype No. 5879.

CLITHROCYTHERIDEA GARRETTI (Howe & Chambers), 1935
Pl. 92, fig. 8

Cytheridea (?) *garretti* HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 14, pl. 1, figs. 4,5, pl. 2, figs. 11,12, pl. 6, figs. 10,11.
Cytheridea (*Clithrocytheridea*) *garretti* STEPHENSON, 1936, Jour. Paleontology, v. 10, no. 8, p. 702, pl. 94, figs. 5,6,10, text-figs. 1,1,o,p; ——, 1942, *ibid.*, v. 16, no. 1, p. 105,110, pl. 18, fig. 1.
Cytheridea (*Cleithrocytheridea*) *garretti* [*sic*] MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 89,94.
Clithrocytheridea garretti STEPHENSON, 1944, Jour. Paleontology, v. 18, no. 5, p. 449,450, pl. 76, fig. 1; ——, 1946, *ibid.*, v. 20, no. 4, p. 327, pl. 42, fig. 18.
Clythrocytheridea [*sic*] *garatti* [*sic*] SCHWEYER, 1949, All-Union Petrol. Sci. Res. Geol. Expl. Inst. (VNIGRI), Trans., n.s. v. 30, pl. 98, pl. 1, fig. 4.
Cleithrocytheridea [*sic*] *garretti* WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 125.
Clithrocytheridea (*Cytheridea*) *garretti* GREKOFF, 1956, Institut Français du Pétrole, p. 44, pl. 7, figs. 127–129.

Diagnosis.—A rather large, elongate species of the genus *Clithrocytheridea* which is characterized by coarse pits which tend to be aligned subparallel to the margins of the carapace, and by its lateral outline which is subrhomboidal.

Remarks.—Males of the species are more elongate and greater in size than the females. This is the type species of the genus *Clithrocytheridea*.

Figured Specimen.—Plesiotype No. 5877, a male right valve from sample No. 1: length, 0.64 mm.; height, 0.30 mm.

Unfigured Specimen.—Plesiotype No. 5878.

CLITHROCYTHERIDEA GRIGSBYI (Howe & Chambers), 1935
Pl. 92, fig. 12

Cytheridea grigsbyi HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 15,16, pl. 1, figs. 2,3, pl. 2, figs. 8,10,17,18, pl. 6, fig. 1; GARRETT, 1936, Jour. Paleontology, v. 10, no. 8, p. 786.
Cytheridea (*Cleithrocytheridea*) *grigsbyi* [*sic*] MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 89,93.
Cytheridea (*Clithrocytheridea*) *grigsbyi* BOLD, 1946, Contr. to the study of Ostracoda with special reference to the Tertiary and Cretaceous microfauna of the Caribbean region, p. 80, pl. 7, figs. 15a,b (apparently wrong as much too small by magnification given).
Clythrocytheridea [*sic*] *grigsbyi* SCHWEYER, 1949, All-Union Petrol. Sci. Res. Geol. Expl. Inst. (VNIGRI), Trans., n.s. v. 30, p. 98, pl. 1, fig. 1.
Clythrocytheridea grigsbyi BOLD, 1950, Jour. Paleontology, v. 24, no. 1, p. 108; BLAKE, 1950, *ibid.*, v. 24, no. 2, p. 175, pl. 29, figs. 13–15.
Cleithrocytheridea [*sic*] *grigsbyi* WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 125.

Diagnosis.—A species of the genus *Clithrocytheridea* characterized by its subtriangular lateral outline and minutely pitted surface.

Figured Specimen.—Plesiotype No. 5879, a whole male carapace from sample No. 5: length, 0.80 mm.; height, 0.40 mm.; thickness, 0.32 mm.

CLITHROCYTHERIDEA SHUBUTENSIS (Stephenson), 1937
Pl. 92, fig. 5

Cytheridea (*Clithrocytheridea*) *shubutensis* STEPHENSON, 1937, Jour. Paleontology, v. 11, no. 2, p. 156, pl. 26, fig. 1, text-fig. 23.

Diagnosis.—This species of *Clithrocytheridea* may be distinguished by its essentially parallel dorsal and ventral margins, subtruncate posterior, by its surface ornamentation which consists of large, deep, closely spaced, subcircular pits which tend to parallel the margins of the carapace, and by a deep flange groove around the anterior, ventral, and posteroventral margins.

Remarks.—Muscle scars, located slightly anterior to the center and in a shallow depression, consist of a vertical row of four adductor scars, below which lie two mandibulars, anterior to which is a single antennal scar. Sexual dimorphism is weakly developed, the females tending to be slightly shorter and a trifle higher than the males.

Figured Specimen.—Plesiotype No. 5880, a female left valve from sample No. 1: length, 0.60 mm.; height, 0.32 mm.

Unfigured Specimen.—Plesiotype No. 5881.

Genus CYAMOCYTHERIDEA Oertli, 1956

CYAMOCYTHERIDEA WATERVALLEYENSIS (Stephenson), 1937
Pl. 91, fig. 2; Pl. 93, fig. 16

Cytheridea (*Haplocytheridea*) *watervalleyensis* STEPHENSON, 1937, Jour. Paleontology, v. 11, no. 2, p. 148,149,154, pl. 26, fig. 3, text-figs. 1,2,9, 10,11,21; BOLD, 1946, Contr. to the study of Ostracoda with special reference to the Tertiary and Cretaceous microfauna of the Caribbean region, p. 80.

Haplocytheridea watervalleyensis WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 124.

Diagnosis.—A species of the genus *Cyamocytheridea* characterized by a smooth carapace with numerous normal pore canals, an anterior vestibule, and a sinuous ventral margin in the right valve.

Remarks.—This species has been placed in the genus *Cyamocytheridea* because of the evenly rounded posterior end, and because of the anterior vestibule—characteristics that are lacking in the genus *Haplocytheridea*.

Figured Specimens.—Plesiotype No. 5882, a right valve from sample No. 1: length, 0.58 mm.; height, 0.27 mm. Plesiotype No. 5883, a left valve from sample No. 1: length, 0.53 mm.; height, 0.30 mm.

Genus HAPLOCYTHERIDEA Stephenson, 1946

HAPLOCYTHERIDEA MONTGOMERYENSIS (Howe & Chambers), 1935
Pl. 91, fig. 7

Cytheridea montgomeryensis HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 17,18, pl. 1, fig. 1, pl. 2, figs. 1–3,7,9, pl. 6, figs. 17,18; GARRETT, 1936, Jour. Paleontology, v. 10, no. 8, p. 786; BERQUIST, 1942, Miss. State Geol. Survey, Geol. Bull. 49, p. 106, pl. 11, fig. 5.

Cytheridea (Haplocytheridea) montgomeryensis STEPHENSON, 1936, Jour. Paleontology, v. 10, no. 8, p. 700,701, pl. 94, figs. 3,4,9, text-figs. 1g,h,j,k; ——, 1937, *ibid.*, v. 11, no. 2, p. 146,153; ——, 1942, *ibid.*, v. 16, no. 1, p. 109, 110, pl. 18. figs. 17,18; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 89.

Haplocytheridea montgomeryensis STEPHENSON, 1946, Jour. Paleontology, v. 20, no. 4, p. 322, pl. 42, fig. 29; SCHWEYER, 1949, All-Union Petrol. Sci. Res. Geol. Expl. Inst. (VNIGRI), Trans., n.s. v. 30, p. 98, pl. 1, fig. 3; BLAKE, 1950, Jour. Paleontology, v. 24, no. 2, p. 176, pl. 29, fig. 16; SWAIN, 1951, USGS Prof. Paper 234-A, p. 20, pl. 1, fig. 18, pl. 2, figs. 1–4; WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 124; POKORNY, 1958, Grundzuge der Zoologischen Mikropaläontologie, p. 2466, fig. 908.

Diagnosis.—This species is characterized by pits arranged in about six curvilinear rows at right angles to the long axis of the carapace and by the possession of several spines around the anterior margins of both valves.

Remarks.—Females of the species tend to be smaller, less elongate, and are usually more sharply pointed at the posteroventral angle.

Figured Specimen.—Plesiotype no. 5884, an entire female carapace from sample No. 5: length, 0.66 mm.; height, 0.40 mm.; width, 0.32 mm.

Subfamily EUCYTHERINAE Puri, 1954
Genus CUSHMANIDEA Blake, 1933
CUSHMANIDEA KEYSERENSIS Krutak, n. sp.
Pl. 92, fig. 6

Diagnosis.—A species of the genus *Cushmanidea* characterized by its smooth carapace which carries a fairly large number of normal pore canals, and in ventral view by extremely faint subparallel ridges which converge posteriorly.

Description.—Carapace in side view very elongate, length being about two and one half times height. Greatest height posterior to the middle; greatest length ventral to the middle; greatest thickness posterior to the middle. Dorsal margin arched slightly upward, paralleling the ventral margin, which is slightly concave just behind the centroventral area. Anterior end acutely rounded; posterior end more broadly rounded, subtruncate in some specimens. Surface of carapace irregularly dotted with scattered normal pore canals which are more heavily concentrated in the middle and ventral areas of the valves.

Viewed from the inside, the valves are moderately deep, translucent, the pits caused by the normal pore canals being visible from the inside. The calcified portion of the inner lamella is widest around the anterior end, forming a conspicuous vestibule. Very fine radial pore canals exist around the entire marginal area. Hingement is lophodont.

Remarks.—This species resembles *C. gosportensis* (Blake) from the Claiborne Eocene Gosport Sand of Little Stave Creek, Alabama, but differs in being shorter and lacking the denticulations around the anterior end. The new species is based on eleven whole carapaces and seventy-one single valves.

Figured Specimen.—Holotype No. 5885, a complete carapace from sample No. 1: length, 0.66 mm.; height, 0.26 mm.; width, 0.24 mm.

Unfigured Specimens.—Paratype Nos. 5885a, 5885b.

CUSHMANIDEA PAPULA Krutak, n. sp.
Pl. 92, fig. 9

Diagnosis.—This species of *Cushmanidea* may be identified by its papillose carapace, great length, and faint denticulations on the anteroventral portion of the carapace.

Description.—Carapace in side view very elongate, length more than two and one half times height. Greatest height along central portion of carapace; greatest length along midline. Dorsal margin arched upward, ventral margin generally parallel to dorsal, concave upward in centroventral area. Anterior end broadly rounded, somewhat produced ventrally. Anteroventral portion of valves bordered by very small denticulations which die out dorsally. Posterior end bluntly rounded, subtruncate. Valves dissimilar in size and shape; right valve smaller than left, having a much less truncate posterior end, the postero-dorsal slope being inclined rearward at a relatively low angle.

Exterior of carapace covered with minute, very closely spaced papillae, those on the ventral side having a slight tendency to parallel the ventral margin. On some specimens, the musculature is visible from the outside of the carapace, the valve being translucent in the area of the muscle node.

On the inside the valves are moderately deep, the greatest depth being posterodorsally. Marginal areas are well developed; a vestibule is present around the anterior end. An incised lip-line is developed just inside the free border of the left valve; an upraised rim just inside the free border of the right valve fits into the incised line of the left. A number of very fine radial pore canals can barely be discerned around the anterior end; a few exist posteriorly. Hingement lophodont.

Remarks.—The new species is based on sixty-one single valves and one whole carapace. This species bears some resemblance to *C. perforata* (Blake) of the Claiborne Eocene Gosport Sand. It differs in having its greatest height posteriorly, being more swollen posteriorly, bearing coarse denticulations around the anteroventral end and in its surface ornamentation, which consists of minute papillae.

Figured Specimen.—Holotype No. 5886, a left valve from sample No. 2: length, 0.74 mm.; height, 0.30 mm.

Unfigured Specimens.—Paratype Nos. 5887, 5888.

CUSHMANIDEA SERANGODES
Krutak, n. sp.
Pl. 92, fig. 10

Diagnosis.—A highly sexually dimorphous species of *Cushmanidea* characterized by surface ornamentation consisting of coarse, circular, irregularly arranged deep pits.

Description.—Carapace in lateral view elongate, length being about two and one-half times height in males. Greatest height in central area; greatest length along the midline, greatest width ventral to the middle of the carapace. Dorsal margin arched slightly upward; ventral margin subparallel to dorsal, slightly concave upward in centroventral area. Anterior end of valves evenly rounded, bearing coarse denticulations ventrally. Posterior end of left and right valves different, that of the left valve being almost truncate, that of the right valve sharply rounded below, making an obtuse angle with the dorsal margin above. Dorsal contact margin slightly sinuous.

Viewed from the inside, the valves are deep and transparent, the exterior pits showing through the carapace. The valves are heavily built; marginal areas are well developed, the anterior end bearing a weak vestibule. The free border of the left valve bears an incised lip-line into which an upraised rim just inside the free border of the right valve fits. Hingement is lophodont.

Remarks.—This species is most closely related to *C. keyserensis* Krutak from the same horizon, but differs in its extremely coarse pitting, possession of a flange groove in the left valve, and slight sinuosity of contact margin along the dorsal margin. The species is based on fifteen single valves and two whole carapaces. Sexual dimorphism is strong, males being much longer and less tumid than the females. The specific name is from the Greek *σηραγγώδης*, meaning full of caverns, porous.

Figured Specimen.—Holotype No. 5889, a male right valve from sample No. 4: length, 0.64 mm.; height, 0.24 mm.

Unfigured Specimens.—Paratype Nos. 5890, 5891.

Subfamily CYTHERINAE Dana, 1853
Genus ACUTICYTHEREIS Edwards, 1944
ACUTICYTHEREIS COCOAENSIS Krutak, n. sp.
Pl. 92, fig. 2

Diagnosis.—A species of *Acuticythereis* ornamented posteroventrally by short raised ribs, and bordered by an incised line that occurs just inside the free border around most of the valve.

Description.—Carapace in lateral view elongate-ovate, produced anteroventrally, longest along midline. Dorsal and ventral margins essentially parallel; anterior end obliquely rounded down, posterior end obliquely rounded up. Right valve subangulate at posterior.

Most of exterior smooth, but near the middle orifices of normal pore canals are prominent.

On the interior the valves are moderately deep; a narrow vestibule is developed anteriorly; relatively straight radial pore canals occur along most of the marginal area. Hingement holamphidont.

Muscle scars consist of two antennals in front of a vertical row of four adductors, and two mandibulars set obliquely below. Another scar occurs dorsal to and about halfway between the adductors and antennals.

Remarks.—The new species is based on twenty-five single valves. Male carapaces are less high and more elongate than females. The species bears some resemblance to *A. laevissima* Edwards of the Miocene Duplin Marl, but differs in its ribbed posteroventral sides, lack of posterior convergence of dorsal and ventral margins, and relatively straight, unbranched radial pore canals.

Figured Specimen.—Holotype No. 5892, a male right valve from sample No. 2: length, 0.70 mm.; height, 0.30 mm.

Unfigured Specimens.—Paratype Nos. 5893, 5894.

Genus CYTHEROMORPHA Hirschmann, 1909
CYTHEROMORPHA CALVA Krutak, n. sp.
Pl. 93, fig. 5

Diagnosis.—A species of *Cytheromorpha* characterized by its essentially smooth carapace.

Description.—Carapace in side view elongate-ovate. Dorsal and ventral margins nearly straight, converging toward the posterior. Anterior end broadly rounded, bordered by a thin compressed rim. Posterior end bluntly rounded. Central portion of carapace slightly inflated, essentially smooth.

Internally, the valves are shallow. Marginal areas are widest anteriorly where a broad vestibule occurs. Widely spaced radial pore canals are present around the anterior end. A few scattered canals are discernible posteriorly. Hingement gongylodont.

Muscle scars, located slightly anterior to the center of the carapace, consist of a slightly curved row of four adductors, below and anterior to which are two oval mandibular scars.

Remarks.—Sexual dimorphism is well developed, males being much more elongate than females. This species is very close to *C. ouachitaensis* Howe & Chambers of the upper Jackson, but differs in its external ornamentation, being essentially smooth. The new species is based on nineteen single valves. The specific name is derived from the Latin *calva*, meaning smooth.

Figured Specimen.—Holotype No. 5895, a female right valve from sample No. 1: length, 0.46 mm.; height, 0.24 mm.

Unfigured Specimens.—Paratype Nos. 5896, 5897, 5898.

Subfamily BRACHYCYTHERINAE Puri, 1954
Genus BRACHCYTHERE Alexander, 1933
BRACHYCYTHERE MISSISSIPPIENSIS (Meyer), 1887
Pl. 91, fig. 10

Cythere mississippiensis MEYER, 1887, Senckenbergische Nat. Ges. Frankfurt, Ber., p. 14, pl. 2, figs. 20,20a,20b.

Diagnosis.—A brachycytherid species distinguished by its extremely large size, heavy curved alae, longitudinal ribs on the posterior half of carapace, and ventral ribs and furrows.

Description.—Carapace in side view oblong-ovate; very large; greatest height at anterior cardinal angle; greatest length along midline. Dorsal margin straight along hingeline, converging strongly with ventral margin. A slight swelling on the front side of the anterior cardinal angle marks the position of an obscure eyespot. Ventral margin obscured in centroventral area by a projecting

ala which curves below the ventral outline. Ventral margin of right valve inturned in front of middle, that of the left valve essentially straight. Anterior end obliquely rounded, rimmed; posterior end blunt, making an obtuse angle with the ventral margin below, and the posterodorsal slope above; it bears three or four broad denticulations on well preserved specimens.

A heavy curved ala, beginning just behind the anteroventral rim, curves down below the ventral margin, and back toward the dorsum where it terminates abruptly just above the posteroventral area. The posterior half of the ala is rimmed and at its posterior termination bears a round node. Five raised longitudinal ridges, between which are deep circular pits, ornament the posterior half of the valves. In ventral view the carapace is rather wide, and bears longitudinal ridges and furrows.

Viewed from the inside the valves are deep and heavily built, greatest depth being posteroventrally. Marginal areas regular, the line of concrescence coinciding with the inner margin. The right valve bears a flange groove around its free border. Hingement hemiamphidont, the left valve bearing a well developed accommodation groove above the median element.

Muscle scars, located on the posterior side of a depression in the central portion of the carapace, consist of five adductors, anterior to which is a single heart-shaped antennal scar.

Remarks.—The species is sexually dimorphous, female valves being higher and more broadly rounded anteriorly and generally more plump. The writer has had access to a large number of Jackson Eocene ostracode collections in which this species occurs, and feels sure that this is the species figured by Meyer in 1887, even though Meyer's description consists of only one sentence and his figures are diagrammatic. My collections have fifteen single valves of the species. It appears to be related most closely to *B. bernardi* Murray & Hussey of the Claiborne Eocene. It differs in its surface ornamentation, being ribbed instead of smooth, having less pronounced alae, by its ribbed and furrowed ventral surface, and generally larger carapace.

Figured Specimen.—Plesiotype No. 5899, a male right valve from sample No. 2: length, 1.00 mm.; height, 0.48 mm.

Unfigured Specimen.—Plesiotype No. 5900.

BRACHYCYTHERE WATERVALLEYENSIS Howe & Chambers, 1935
Pl. 91, fig. 1

Brachycythere watervalleyensis HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 46,47, pl. 3, figs. 1–6, pl. 4, fig. 1, pl. 6, fig. 7; GARRETT, 1936, Jour. Paleontology, v. 10, no. 8, p. 786; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 90; BERQUIST, 1942, Miss. State Geol. Survey, Geol. Bull. 49, p. 109, pl. 11, figs. 21,22; MURRAY & HUSSEY, 1942, Jour. Paleontology, v. 16, no. 2, p. 179, pl. 28, figs. 2,3, text-fig. 2, figs. 5,6; WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 124.

Diagnosis.—A species of the genus *Brachycythere* characterized by its ovate-alate outline, the alae often bearing backwardly directed spines at their posterior ends, smooth carapace, and in ventral view by the four projecting rims at the anterior end.

Remarks.—The hinge in this species is typically hemiamphidont, but in some specimens the anterior element is irregularly crenulate, which feature was used by Mandelstam (1958) to create the genus *Digmocythere*. However, not all specimens show this, and the writer feels justified in referring this species to the genus *Brachycythere*.

Five adductor muscle scars occur on the posterior side of a small depression which is located anterior to the center of the carapace. They consist of an upper oval scar, two others side by side below it, and a large ventral spot consisting of two fused scars. Anterior to these is a V-shaped spot consisting of two antennal scars, below which is a V-shaped mandibular scar.

Figured Specimen.—Plesiotype No. 5901, a female left valve from sample No. 3: length, 0.70 mm.; height, 0.40 mm.

Unfigured Specimens.—Plesiotype Nos. 5902, 5903.

Subfamily TRACHYLEBERINAE Hornibrook, 1952

Genus ACTINOCYTHEREIS Puri, 1953

ACTINOCYTHEREIS GIBSONENSIS (Howe & Chambers), 1935
Pl. 91, fig. 4

Cythereis gibsonensis HOWE & CHAMBERS, 1935,

La. Geol. Survey, Geol. Bull. 5, p. 29,30, pl. 1, fig. 22, pl. 6, figs. 21,22; GARRETT, 1936, Jour. Paleontology, v. 10, no. 8, p. 786; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 89; BERQUIST, 1942, Miss. State Geol. Survey, Geol. Bull. 49, p. 107, pl. 11, figs. 9,10.
Actinocythereis gibsonensis PURI, 1953, Am. Midland Naturalist, v. 49, p. 182, pl. 2, figs. 11,12.

Diagnosis.—A species of *Actinocythereis* recognized in dorsal view by a double row of five spines, compressed ends, and short raised rims that extend down from the two prominent eyespots.

Remarks.—A closely related form, possessing double or triple spines, and long raised rims around the anterior, and plumper than the typical species occurs in this horizon. It may be the female of the species.

Figured Specimen.—Plesiotype No. 5904, a male right valve from sample No. 1: length, 0.62 mm.; height, 0.28 mm.

Unfigured Specimens.—Plesiotype Nos. 5905, 5906.

Genus "ARCHICYTHEREIS" Howe, 1936
"ARCHICYTHEREIS" YAZOOENSIS (Howe & Chambers), 1935
Pl. 93, fig. 17

Cythereis yazooensis HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 38,39, pl. 1, fig. 6, pl. 6, figs. 29,30; GARRETT, 1936, Jour. Paleontology, v. 10, no. 8, p. 786; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 90,96; BERQUIST, 1942, Miss. State Geol. Survey, Geol. Bull. 49, p. 108, pl. 11, fig. 17.
Archicythereis yazooensis (HOWE & CHAMBERS), by HOWE, *in* Howe & Law, 1936, La. Geol. Survey, Geol. Bull. 7, p. 57; WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 124.

Diagnosis.—This "species," which is probably a young molt of some trachyleberid form, is recognized by its fragile, glassy carapace, spinose anterior, ventral, and posterior margins, and toothless left valve.

Remarks.—This "species" of the synthetic genus *Archicythereis* occurs commonly in the Jackson Eocene, and as presently known is restricted to this horizon.

Figured Specimen.—Plesiotype No. 5907, a right valve from sample No. 4: length, 0.64 mm.; height, 0.34 mm.

Unfigured Specimen.—Plesiotype No. 5908.

Genus BUNTONIA Howe, 1935
BUNTONIA SHUBUTAENSIS Howe, 1935
Pl. 93, fig. 15

Buntonia shubutaensis HOWE, 1935, (juvenile) *in* Howe & Chambers, 1935, La. Geol. Survey, Geol. Bull. 5, pp. 23,24, pl. 4, figs. 4,5, pl. 5, fig. 7; HOWE, 1947, Am. Assoc. Petrol. Geol.-Soc. Economic Paleontologists and Mineralogists-Soc. Explor. Geophysicists Joint Annual Meeting, p. 50; WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 125.
Cythereis (?) *israelskyi* HOWE & PYEATT, (adult) *in* Howe & Chambers, 1935, La. Geol. Survey, Geol. Bull. 5, p. 33, pl. 1, figs. 19–21, pl. 4, figs. 7–9; BERQUIST, 1942, Miss. State Geol. Survey, Geol. Bull. 49, p. 107, pl. 11, fig. 12.
Pyricythereis israelskyi HOWE & LAW, 1936, La. Geol. Survey, Geol. Bull. 7, p. 65.
Pyricythereis cf. *P. israelskyi* MCLEAN, 1947, Philadelphia Acad. Nat. Sci., Notulae Naturae, p. 8.

Diagnosis.—A sexually dimorphous species of the genus *Buntonia* characterized by dissimilar valves, and surface ornamentation that is different on the anterior and posterior halves of the valves; the anterior half being essentially smooth, the posterior half marked by a series of longitudinal ridges which are connected by cross riblets.

Figured Specimen.—Plesiotype No. 5909, a female right valve from sample No. 2: length, 0.50 mm.; height, 0.24 mm.

Unfigured Specimen.—Plesiotype No. 5910.

Genus ECHINOCYTHEREIS Luri, 1954
ECHINOCYTHEREIS JACKSONENSIS (Howe & Pyeatt), 1935
Pl. 91, fig. 9

Cythereis (?) *jacksonensis* HOWE & PYEATT, 1935, *in* Howe & Chambers, 1935, La. Geol. Survey, Geol. Bull. 5, p. 35,36, pl. 1, figs. 23,24, pl. 6, fig. 31; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 90; BERQUIST, 1942, Miss. State Geol. Survey, Geol. Bull. 49, p. 108, pl. 11, fig. 14; BOLD, 1946, Contr. to the study of Ostracoda with special reference to the Tertiary and Cretaceous microfauna of the Caribbean region, p. 89, pl. 10, fig. 9.
Cythereis jacksonensis GARRETT, 1936, Jour. Paleontology, v. 10, no. 8, p. 786; WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 125, pl. 1, fig. 14.
Echinocythereis jacksonensis PURI, 1953, Fla. Geol. Survey, Geol. Bull. 36, p. 260.

Diagnosis.—A species of the genus *Echinocythereis* ornamented with a series of tiny nodules which are aligned, tending to form

hexagonal, pentameral, or angular patterns.

Remarks.—Muscle scars, located in front of the center, consist of four adductors in a vertical row, the third from the bottom being long, thin, and inclined forward, the topmost scar crescent shaped. Two antennal scars are developed in front of the top two adductors, the bottom one farther anterior than the top. Dorsal to and about midway between the adductors and the antennals is an oval scar which is bisected by a transverse line. This scar is probably a composite one.

Figured Specimen.—Plesiotype No. 5911, a left valve from sample No. 1: length, 0.67 mm.; height, 0.40 mm.

Unfigured Specimen.—Plesiotype No. 5912.

Genus HENRYHOWELLA Puri, 1957
HENRYHOWELLA FLORIENENSIS (Howe & Chambers), 1935
Pl. 91, fig. 8

Cythereis florienensis HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 28,29, pl. 1, fig. 14, pl. 6, figs. 14,15; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 89; WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 125, pl. 1, fig. 16.

Cythereis deusseni HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 27,28, pl. 1, fig. 15, pl. 6, figs. 2,3; HOWE & LAW, 1936, La. Geol. Survey, Geol. Bull. 7, p. 58; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 89.

Diagnosis.—This species of *Henryhowella* is characterized by its coarsely reticulate carapace, the reticulations tending to form low spines, five of which project above the dorsal margin of either valve.

Figured Specimen.—Plesiotype No. 5913, a whole carapace from sample No. 1: length, 0.66 mm.; height, 0.34 mm.; width, 0.32 mm.

Genus TRACHYLEBERIS Brady, 1898
TRACHYLEBERIS MONTGOMERYENSIS (Howe & Chambers), 1935
Pl. 91, fig. 3

Cythereis montgomeryensis HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, pp. 37,38, pl. 1, figs. 13,16, pl. 2, figs. 22,23, pl. 6, figs. 19,20; GARRETT, 1936, Jour. Paleontology, v. 10, no. 8, p. 786; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 90,96; BERQUIST, 1942, Ark. Geol. Survey, Geol. Bull. 49, p. 108, pl. 11, figs. 15,16; STEPHENSON, 1944, Jour. Paleontology, v. 18, no. 5, p. 450, 451, pl. 76, fig. 7; BOLD, 1950, *ibid.*, v. 24, no. 1, p. 108; WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 125, pl. 1, fig. 12.

Trachyleberis montgomeryensis PURI, 1953, Am. Midland Naturalist, v. 49, p. 176, pl. 1, figs. 4,5, text-figs. A,B.

Diagnosis.—A trachyleberid species ornamented with heavy, prominent spikes, and bordered by a thick, heavy, raised rim which bears a double row of spines around its anterior, ventral, and posterior margins.

Remarks.—Muscle scars, located on the posterior side of a shallow pit in the center of the carapace, consist of four adductors in an inclined row, one V-shaped scar in the pit and two tiny mandibular scars set obliquely below the pit. Sexual dimorphism is strong, males being much more elongate and relatively lower in height than the females.

Figured Specimen.—Plesiotype No. 5914, a left valve from sample No. 1: length, 0.67 mm.; height, 0.38 mm.

Unfigured Specimen.—Plesiotype No. 5915.

Genus TRIGINGLYMUS Blake, 1950
TRIGINGLYMUS GNYTHOPHOREUS Krutak, n. sp.
Pl. 93, figs. 4,8,11

Diagnosis.—A triginglymid species characterized in lateral outline by its produced anteroventral end, low rounded anterior rim, and longitudinally pitted surface.

Description.—Carapace in side view elongate, plump, length being about twice height. Dorsal and ventral margins parallel; both ends rounded, the anterior obliquely.

Surface of carapace pitted. A low rounded rim, paralleling the anterior, develops just inside the anterior outline. A smooth, transparent "lucid" spot near the center of the carapace marks the position of the muscle node.

Viewed from the inside, the valves are rather deep, the interior divided by a low ridge behind the muscle pit. Marginal areas regular, widest anteriorly. Threadlike radial pore canals are numerous anteriorly, less so posteriorly.

Hingement holamphidont, modified in both valves by "anti-slip" teeth. A lobelike, longitudinally elongate projection (anti-slip tooth) develops just below the dorsal groove and behind the anterior socket in the right

valve, and below the dorsal ridge and behind the anterior tooth in the left, being more depressed in this valve.

Muscle scars, located on the posterior border of a shallow pit which lies somewhat above and anterior to the middle of the carapace, consist of a vertical row of four adductors in front of which is a curved antennal scar, anteroventral to which are two mandibular scars.

Remarks.—This species differs from *T. hyperochus* Blake of the Claiborne Gosport Sand in several ways: in its lateral outline, being less high and more produced anteroventrally; in its almost truncate posterior end; being less swollen posteroventrally; having a low rim paralleling the anterior end; and in its surface ornamentation, which consists of pits instead of reticulations. Females are much more tumid posteriorly, and generally higher than the males although relative length stays about the same. The new species is based on eighty-four single valves and fourteen whole carapaces. The specific name is derived from the Greek γνύθος, cave, pit, or hollow, and φορεύς, bearer, carrier.

Figured Specimens.—Holotype No. 5916, a male right valve from sample No. 1: length, 0.47 mm.; height, 0.23 mm. Paratype No. 5917, a male left valve from sample No. 1: length, 0.49 mm.; height, 0.23 mm.

Unfigured Specimen.—Paratype No. 5918.

Subfamily CYTHERETTINAE Triebel, 1952
Genus CYTHERETTA G. W. Muller, 1894
CYTHERETTA ALEXANDERI Howe & Chambers, 1935
Pl. 91, figs. 5,6

Cytheretta alexanderi HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 45,46, pl. 5, figs. 17–21, pl. 6, figs. 27,28; GARRETT, 1936, Jour. Paleontology, v. 10, no. 8, p. 786; HOWE & LAW, 1936, La. Geol. Survey, Geol. Bull. 7, p. 58; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, pp. 90,95; BERQUIST, 1942, Miss. State Geol. Survey, Geol. Bull. 49, p. 109, pl. 11, fig. 20; BLAKE, 1950, Jour. Paleontology, v. 24, no. 2, p. 177, pl. 30, figs. 1–3; PURI, 1952, Jour. Paleontology, v. 26, no. 2, p. 208,209, pl. 40, figs. 1,2; WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 125, pl. 1, fig. 15; PURI, 1957, Fla. Geol. Survey, Geol. Bull. 38, p. 195, pl. 7, figs. 1–4.

Cythereis (?) catahoulana HOWE & PYEATT, 1935, *in* Howe & Chambers, 1935, La. Geol. Survey, Geol. Bull. 5, p. 25,26, pl. 3, fig. 7, pl. 6, figs. 25,26; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 90,95.

Cythereis (?) *catahoulana* var. *pyeatti* HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 26,27, pl. 3, figs. 20,21; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 89,95.

Cytheretta cf. *C. alexanderi* SWAIN, 1951, USGS Prof. Paper 234-A, p. 47, pl. 6, figs. 23–25.

Cytheretta daytonensis [*sic*] PURI, 1957, Fla. Geol. Survey, Geol. Bull. 38, p. 195, pl. 7, figs. 1–3.

Diagnosis.—A species of *Cytheretta* ornamented with longitudinal, slightly raised, smooth ridges between which are rows of pits.

Remarks.—There appears to be a gradation in the intensity of pitting; some specimens show a very faint tendency to develop the pits, and in some they are entirely lacking.

Muscle scars consist of a V-shaped antennal scar in front of the vertical row of four adductors (the third from the bottom of which is a fused scar composed of two elements), a curved scar above and anterior to the top adductor, and another scar just under the hingement. A single mandibular scar occurs at the open end of the S-loop formed by the inner margin at the anterior end.

Figured Specimens.—Plesiotype No. 5919, a left valve from sample No. 1: length, 0.76 mm.; height, 0.44 mm. Plesiotype No. 5920, a right valve from sample No. 2: length 0.84 mm.; height, 0.40 mm.

Subfamily HEMICYTHERINAE Puri, 1953
Genus ABSONOCYTHEROPTERON Puri, 1957
ABSONOCYTHEROPTERON WATERVALLEYENSIS Krutak, n. sp.
Pl. 92, fig. 11

Diagnosis.—This species is recognized by its faintly sculptured carapace, weak alae, and lack of a subcentral tubercle.

Description.—Carapace in lateral view ovate-elongate; highest at anterior cardinal angle, longest just below the midline, thickest posteroventrally; arrowhead-like in dorsal view. Dorsal outline straight along hingeline, swelling up and around a slightly elevated eyespot at the anterior cardinal angle, converging rather strongly toward the posterior. Ventral margin obscured by the ventral swelling of the valve. Anterior end obliquely rounded, posterior end more nar-

rowly rounded. Left valve overlaps right slightly at the anterior cardinal angle. Ventral side of valves almost flat, bearing longitudinal striations. Exterior of carapace essentially smooth except ventrally where a series of irregular depressions occurs. These are bordered by a shallow longitudinal furrow which parallels the ventral ala.

Viewed from the inside, the valves are rather deep; marginal areas are well developed; a weak vestibule is present anteriorly. Radial pore canals are numerous; approximately seven can be seen posteriorly and posteroventrally; numerous canals exist around the anterior marginal area.

Hingement holamphidont. Muscle scars consist of four adductor scars in a vertical row, in front of which are apparently two obliquely inclined antennal scars.

Remarks.—The species shows strong sexual dimorphism, males being much longer and less plump. This species is based on twelve single valves and thirteen whole carapaces. The type species *A. carinata* Puri from the Crystal River Formation of Florida is set apart by its highly ornamented carapace, prominent subcentral tubercle, and more prominent alae. This species has been compared with Ocala species of the type species and on the basis of muscle scars may be questionably placed in the Hemicytherinae.

Figured Specimen.—Holotype No. 5921, a complete male carapace from sample No. 5: length, 0.82 mm.; height, 0.42 mm.; width, 0.42 mm.

Unfigured Specimens.—Paratype Nos. 5922, 5923.

Genus HERMANITES Puri, 1954

HERMANITES (?) HYSONENSIS (Howe & Chambers), 1935

Pl. 92, fig. 7

Cythereis hysonensis HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 31,32, pl. 1, fig. 8, pl. 6, figs. 23,24; GARRETT, 1936, Jour. Paleontology, v. 10, no. 8, p. 786; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 89,95; WILBERT, 1953, Ark. Geol. Survey, Geol. Bull. 19, p. 125.

Cythereis cf. *C. hysonensis* SWAIN, 1948, Maryland Board of Natural Resources, Cretaceous and Tertiary Subsurface Geology, p. 201, pl. 13, fig. 10.

Diagnosis.—A species of *Hermanites* characterized by a coarsely reticulate surface with a prominent node just in front of the center, three longitudinal ribs, an inclined rib that begins at the posterior cardinal angle, extends forward and down, terminating at its junction with the ventral rib, and seven or eight normal pore canals that parallel the anterior just inside the inner margin.

Remarks.—Muscle scars, located in a deep pit, consist of a curved row of four adductors with a variable number of scars in front. Since internal details on the type species are not visible it is questionably referred to this genus on the basis of its holamphidont hinge and shape. It differs from the genus *Cythereis* in its muculature, bulbous radial pore canals, holamphidont hinge, and well developed normal pore canals.

Figured Specimen.—Plesiotype No. 5924, a left valve from sample No. 4: length, 0.66 mm.; height, 0.32 mm.

Unfigured Specimen.—Plesiotype No. 5925.

HERMANITES (?) DOHMI (Howe & Chambers), 1935

Pl. 93, fig. 14

Cythereis hysonensis var. *dohmi* HOWE & CHAMBERS, 1935, La. Geol. Survey, Geol. Bull. 5, p. 32, pl. 1, fig. 9; MONSOUR, 1937, Am. Assoc. Petrol. Geol. Bull., v. 21, no. 1, p. 90.

Jugosocythereis tricarinata PURI, 1957, Fla. Geol. Survey, Geol. Bull. 38, p. 201, pl. 12, figs. 1–10.

Diagnosis.—This species is distinguished by its shortness, smooth exterior except for the orifices of normal pore canals, and strongly pronounced muscle node in front of the center.

Remarks.—The species differs from *H.* (?) *hysonensis* (Howe & Chambers) in being shorter, lacking the reticulate surface ornamentation, and having a more pronounced muscle node. It has been compared to topotypes of the type species of *Hermanites* and has the shape but not the ornamentation of the type. Since internal details on the type species are not visible, it is questionably placed in this genus. It also appears to be distinct enough to be a separate species and not a variety of *H.* (?) *hysonensis* (Howe & Chambers).

Muscle scars, located in a deep pit, consist of a curved row of four elongate adductors with three or four scars in front.

Figured Specimen.—Plesiotype No. 5926,

a right valve from sample No. 1: length, 0.52 mm.; height, 0.26 mm.

Unfigured Specimen.—Plesiotype No. 5927.

REFERENCES

BERQUIST, H. R., 1942, Scott County fossils, Jackson Foraminifera and Ostracoda: Miss. State Geol. Survey, Geol. Bull. 49, 146 p., 10 pls.

BLAKE, D. B., 1950, Gosport Eocene Ostracoda from Little Stave Creek, Alabama: Jour. Paleontology, v. 24, p. 174–184, pls. 29,30.

BLANPIED, B. W. *et al.*, 1934, Stratigraphy and paleontological notes on the Eocene (Jackson Group), Oligocene, and Lower Miocene of Clarke and Wayne Counties, Mississippi: Shreveport Geol. Soc. Guidebook, 11th Annual Field Trip.

VAN DEN BOLD, W. A., 1946, Contribution to the study of Ostracoda with special reference to the Tertiary and Cretaceous microfauna of the Caribbean Region: J. H. Debussey, Amsterdam, 167 p., 18 pls.

——, 1950, A checklist of Cuban Ostracoda: Jour. Paleontology, v. 24, p. 107–109.

COOKE, C. W., 1915, The Age of the Ocala Limestone: USGS Prof. Paper 95, p. 116.

——, 1926, The Cenozoic formations *in* Geology of Alabama: Ala. Geol. Survey Special Rept 14, p. 274,275.

——, 1933, Definition of Cocoa Sand Member of Jackson Formation: Am. Assoc. Petroleum Geologists Bull., v. 17, no. 11, p. 1387,1388.

CUSHMAN, J. A., 1925, Eocene Foraminifera from the Cocoa Sand of Alabama: Contr. Cushman Lab. Foram. Res., v. 1, pt. 3, no. 16, p. 65–68, pl. 10.

——, 1928, Additional Foraminifera from the Upper Eocene of Alabama; Contr. Cushman Lab. Foram. Res., v. 4, pt. 3, no. 64, p. 73–79, pl. 10.

——, 1946, A rich foraminiferal fauna from the Cocoa Sand of Alabama: Contr. Cushman Lab. Foram. Res, Special Pub. 16, 40 p., 8 pls.

EDWARDS, R. A., 1944, Ostracoda from the Duplin Marl (Upper Miocene) of North Carolina: Jour. Paleontology, v. 18, p. 505–528, pls. 85–88.

GARRETT, J. B., JR., 1936, Occurrence of *Nonionella cockfieldensis* at Claiborne, Alabama: Jour. Paleontology, v. 10, p. 785,786.

GREKOFF, N., 1956, Guide pratique pour la determination des ostracodes postpaléozoïques: Inst. Franç. Pétrole, 95 p., 16 pls.

HOWE, H. V., 1934, The Ostracode genus *Cytherelloidea* in the Gulf Coast Tertiary: Jour. Paleontology, v. 8, p. 29–34, pl. 5.

——, 1942, Fauna of the Glendon Formation at its type locality: Jour. Paleontology, v. 16, p. 264–271.

——, 1947, Revision of the ostracod genus *Buntonia:* A.A.P.G.-S.E.P.M.-S.E.G. Joint Annual Meeting, March 24–27, Los Angeles, (abstract), p. 50.

——, 1947b, Status of micropaleontology in Eastern Gulf Region: Am. Assoc. Petroleum Geologists Bull., v. 31, no. 4, p. 713–730.

——, 1951, New Tertiary ostracode fauna from Levy County, Florida: Florida Geol. Survey, Geol. Bull. 34, pt. 1, p. 1–43, 5 pls.

——, 1955, Handbook of Ostracod Taxonomy: La. State Univ. Press, Baton Rouge, La, 389 p.

—— & CHAMBERS, J., 1935, Louisiana Jackson Eocene Ostracoda: La. Geol. Survey, Geol. Bull. 5, 96 p., 6 pls.

—— & graduate students, 1935, Ostracoda of the *Arca* zone of the Choctawhatchee Miocene of Florida: Florida Geol. Survey, Geol. Bull. 13, p. 1–37, pls. 1–4.

—— & LAW, J., 1936, Louisiana Vicksburg Oligocene Ostracoda: La. Geol. Survey, Geol. Bull. 7, 96 p., 6 pls.

LUCAS, F. A., 1900, The Pelvic girdle of Zeuglodon, *Basilosaurus cetoides* (Owen), with notes on other portions of the skeleton: U. S. Nat. Mus. Proc., v. 23, p. 327–332.

MANDELSTAM, M. I., 1958, New genera and species of Ostracoda *in* Microfauna of the U.S.S.R., Part 9: Trudi Vnigri, v. 150, p. 277,278 (in Russian).

MCLEAN, J. D., JR., 1947, Oligocene and Lower Miocene microfossils from Onslow County, North Carolina: Philadelphia Acad. Nat. Sci., Notulae Naturae, 9 p.

MEYER, OTTO, 1887, Beitrag zur Kenntnis der Fauna des Alttertiars von Mississippi und Alabama: Senckenbergische Naturf. Gesell. Frankfurt, Bericht, p. 3–22, pls. 1,2.

MONSOUR, E., 1937, Micropaleontologic analysis of Jackson Eocene of Eastern Mississippi: Am. Assoc. Petroleum Geologists Bull., v. 21, no. 1, p. 80–96.

MURRAY, G. E., 1947, Cenozoic deposits of Central Gulf Coastal Plain: Am. Assoc. Petroleum Geologists Bull., v. 31, no. 10, p. 1825–1850.

—— & HUSSEY, K. M., 1942, Some Tertiary Ostracoda of the genera *Alatacythere* and *Brachycythere:* Jour. Paleontology, v. 16, p. 164–182, pls. 27,28.

POKORNY, VLADIMIR, 1958, Grundzuge der Zoologischen Mikropaläontologie: Veb Deutscher verlag der Wissenschaften, Berlin, 453 p., illus.

PURI, H. S., 1952, Ostracoda genera *Cytheretta* and *Paracytheretta* in America: Jour. Paleontology, v. 26, p. 199–212, pls. 39,40.

——, 1953, Ostracode genus *Trachyleberis* and its ally *Actinocythereis:* Am. Midland Naturalist, v. 49, p. 171–187, 2 pls.

——, 1953a, Contribution to the study of the Miocene of the Florida Panhandle, Part III, Ostracoda: Florida Geol. Survey, Geol. Bull. 36, p. 215–345, pls. 1–17.

——, 1955, *Hermanites*, a new name for *Hermania*, Puri, 1954: Jour. Paleontology, v. 29, p. 558.

——, 1957, Stratigraphy and zonation of the Ocala Group, Part III, Ostracoda: Florida Geol. Survey, Geol. Bull. 38, p. 185–244, pls. 1–15.

SCHMIDT, RUTH A., 1948, Ostracoda from the Upper Cretaceous and Lower Eocene of Mary-

land, Delaware, and Virginia: Jour. Paleontology, v. 22, p. 389–431, pls. 61–64.

SCHWEYER, A. V., 1949, Fundamentals of the morphology and classification of Pliocene and Post-Pliocene Ostracoda: All-Union Petrol. Sci. Res. Geol. Expl. Inst. (VNIGRI), Trans., n.s., v. 30 (in Russian).

SEXTON, J. V., 1951, The Ostracode *Cytherelloidea* in North America: Jour. Paleontology, v. 25, p. 808–816, pls. 115–117.

STEPHENSON, M. B., 1936, Shell structure of the ostracode genus *Cytheridea:* Jour. Paleontology, v. 10, p. 695–703, pl. 94.

——, 1937, Middle Tertiary Ostracoda of the genus *Cytheridea:* Jour. Paleontology, v. 11, p. 145–159, pl. 26.

——, 1941, Notes on the subgenera of the ostracode genus *Cytheridea:* Jour. Paleontology, v. 15, p. 424–429.

——, 1942, Some Claiborne Eocene Ostracoda of the genus *Cytheridea* from the Gulf Coast: Jour. Paleontology, v. 16, p. 105–115, pl. 18.

——, 1944, Ostracoda from the Reklaw Eocene of Bastrop County, Texas: Jour. Paleontology, v. 18, p. 448–454, pl. 76.

——, 1946, Weches Eocene Ostracoda from Smithville, Texas: Jour. Paleontology, v. 20, p. 297–344, pls. 42–45.

SUTTON, A. H. & WILLIAMS, J. R., 1939, Ostracoda from the Weches Formation at Smithville, Texas: Jour. Paleontology, v. 13, p. 561–574, pls. 63,64.

SWAIN, F. M., 1946, Ostracoda from the Tertiary of Florida: Jour. Paleontology, v. 20, p. 374–383, pls. 54,55.

——, 1948, Ostracoda from the Hammond Well: Maryland Board of Natural Resources, Cretaceous and Tertiary Subsurface Geology, p. 187–213, pls. 12–14.

——, 1951, Ostracoda from wells in North Carolina, Part I, Cenozoic Ostracoda: USGS Prof. Paper 234-A, 55 p., 7 pls.

SYLVESTER-BRADLEY, P. C., 1941, The Shell structure of the Ostracoda and its application to their palaeontological investigation: Ann. Mag. Nat. Hist., Ser. 11, v. viii, p. 1–33.

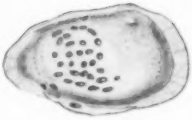
TURNBULL, W. D., 1948, Cocoa Sand type locality: Jour. Paleontology, v. 22, p. 372.

WILBERT, L. J., JR., 1953, The Jacksonian Stage in southeastern Arkansas: Arkansas Geol. Survey, Geol. Bull. 19, 125 p.

EXPLANATION OF PLATE 93

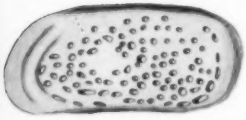
FIG. *1*—*Loxoconcha creolensis* Howe & Chambers. Left valve, ×75. Plesiotype No. 5857.
2—*Loxoconcha cocoaensis* Krutak, n. sp. Right valve, ×73. Holotype No. 5864.
3—*Loxoconcha watervalleyensis* Krutak, n. sp. Right valve, ×75. Holotype No. 5867.
4,8,11—*Triginglymus gnythophoreus* Krutak, n. sp. *4*, exterior male left valve, ×75, paratype No. 5917. *8*, interior same valve, ×75. *11*, interior male right valve, ×75, holotype No. 5916.
5—*Cytheromorpha calva* Krutak, n. sp. Female right valve, ×75. Holotype No. 5895.
6—*Loxoconcha concentrica* Krutak, n. sp. Right valve, ×75. Holotype No. 5861.
7,10—*Cytherelloidea montgomeryensis* Howe. *7*, female left valve, ×75, plesiotype No. 5850. *10*, male left valve, ×75, plesiotype No. 5851.
9—*Loxoconcha jacksonensis* Howe & Chambers. Right valve, ×75. Plesiotype No. 5859.
12—*Cytheropteron montgomeryensis* Howe & Chambers. Right valve, ×75. Plesiotype No. 5873.
13—*Cytherelloidea cocoaensis* Krutak, n. sp. Left valve view of a complete female carapace, ×75. Holotype No. 5852.
14—*Hermanites* (?) *dohmi* (Howe & Chambers). Right valve, ×75. Plesiotype No. 5926.
15—*Buntonia shubutaensis* Howe. Female right valve, ×75. Plesiotype No. 5909.
16—*Cyamocytheridea watervalleyensis* (Stephenson). Left valve, ×75. Plesiotype No. 5883.
17—*"Archicythereis" yazooensis* (Howe & Chambers). Right valve, ×75. Plesiotype No. 5907.

1



2

3



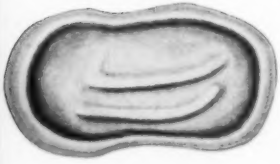
4

5

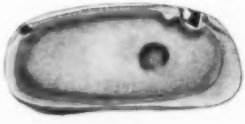
6

7

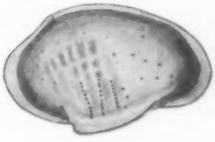
9



10



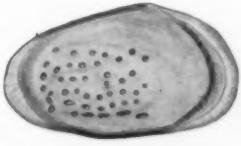
8



12

13

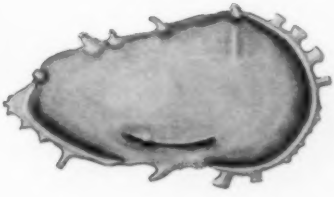
11



15

16

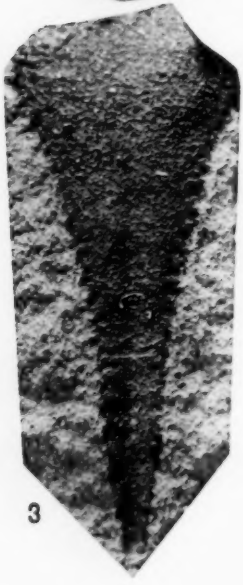
14



17

1

2

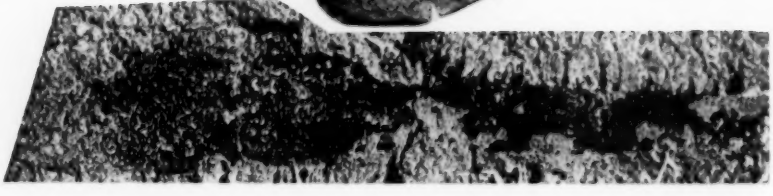


3

4

5

6



7

JOURNAL OF PALEONTOLOGY, V. 35, NO. 4, P. 789–835, PLS. 94–96, 4 TEXT-FIGS., JULY, 1961

THE SILURIAN EURYPTERIDA OF THE WELSH BORDERLAND

ERIK N. KJELLESVIG-WAERING
Pan American Argentina Oil Company, Buenos Aires

ABSTRACT—A review of the eurypterid collections made by early collectors in the Silurian of the Welsh Borderland and originally described by J. W. Salter (1859) and Henry Woodward (1866–78) in their monographs. The family Pterygotidae is revised to include two genera, each of which is further divided into two subgenera. Thus the genus *Pterygotus* Agassiz, 1844, is divided into *Pterygotus* (*Pterygotus*) Agassiz, 1844, and *Pterygotus* (*Acutiramus*) Ruedemann, 1935, whereas *Erettopterus* Salter, 1859, is considered a genus with two subgenera recognized, namely, *Erettopterus* (*Erettopterus*) Salter, 1859, and *Erettopterus* (*Truncatiramus*), new subgenus. A new genus, *Parahughmilleria*, referred to the family Hughmilleriidae, is described, and the genus *Hughmilleria* Sarle, 1903, is divided into two subgenera: *Hughmilleria* (*Hughmilleria*) Sarle, 1903, and *Hughmilleria* (*Nanahughmilleria*), which is proposed as new. Eleven new species and subspecies are described. The taxonomic problems involving the genotype of *Pterygotus* are discussed and the species, *Pterygotus problematicus* Agassiz, is considered *nomen vanum*. The plates of the dorsal side of the metastoma, hitherto unknown, are described. A checklist of the Eurypterida of the Silurian of the Welsh Borderland is given.

THE year 1859 was highly important in the advancement of our knowledge of the Eurypterida as almost simultaneously Hall, Nieszkowski, and Huxley & Salter, each working independently in New York, Russia and England respectively, published their well known monographs. Nieszkowski's report was restricted mainly to the morphology of *Eurypterus remipes tetragonophthalmus* Fischer, but the other two papers, al-

EXPLANATION OF PLATE 94

FIG. 1—Two uncrushed carapaces in sandstone of *Hughmilleria* (*H.*) *banksii* (Salter), ×1.3, from the Downtonian at Bradnor Hill, Kingston, Herefordshire, England; collected by R. Gibbs, about 1860. Specimen No. 89471 in Geological Survey and Museum, London.

2—Same specimen but enlarged to show the characteristic pointed anterior and the large lateral eye. ×2.1.

3—Telson of *Hughmilleria* (*Hughmilleria*) (?) *acuminata* (Salter), ×3.6, preserved in sandstone in an uncrusted condition. The slight dorsal carina and the prominent scale-like serrations on the margins are clearly preserved. From the Downton sandstone at Ludford Lane, Shropshire, England, collected by Alfred Marston about 1857. Specimen No. In 44575 in the British Museum (Natural History)

4—The holotype of *Erettopterus* (*Erettopterus*) *spatulatus* Kjellesvig-Waering, n. sp., ×1.3. The metasomal tergites and telson, from the Downtonian at the Railway Cutting, Ludlow, Shropshire, England, collected by Robert Lightbody, 1858–59. Specimen No. 89397 in the Geological Survey and Museum, London and counterpart, No. In 44563 in the British Museum (Natural History). This specimen was figured by Salter (1859 pl. 12, fig. 23) and Woodward (1866–1878, pl. 15, fig. 4) and is refigured in Text-fig. 25 and Pl. 96, fig. 4.

5—*Erettopterus* (*Erettopterus*) *spatulatus* Kjellesvig-Waering, n. sp., ×5.5. The carapace with well preserved lateral eys and ocellar mound. From the Downton sandstone at Ludford Lane, Shropshire, England. Specimen No. In 43794 in the British Museum (Natural History). The counterpart is shown in Pl. 96, fig. 3.

6—*Erettopterus* (*Erettopterus*) *spatulatus* Kjellesvig-Waering, n. sp., ×5.5. The carapace, which retains a well preserved ocellar mound and ocelli. From the Temeside Shale at Tin Mill Race, Downton Castle, Herefordshire, England, collected by Robert H. Denison. Specimen No. PE 4978 in the Chicago Natural History Museum.

7—*Erettopterus* (*Erettopterus*) *spatulatus* Kjellesvig-Waering, n. sp., ×3. The hand and fixed ramus of the chelicera. The hand as well as the stem of the fixed ramus is brown in color which contrasts with the black of the teeth. Preserved in olive shale from the Temeside shale at Tin Mill Race, Downton Castle, Herefordshire, England, collected by Robert H. Denison. Specimen No. PE 5124 in the Chicago Natural History Museum. The same specimen is illustrated on Text-fig. 3, fig. 34.

though also treating as fully with the morphology of the Eurypterida, included the description of numerous Eurypterida, which today still remain among the most important and best known. These papers, essentially and in effect, represented the start of eurypterid taxonomy.

Previous to 1859, eurypterids were poorly known as the first was described and named by DeKay in 1825 from the Silurian of New York (*Eurypterus remipes remipes*) after being discovered and described, but not named, by S. L. Mitchill in 1818 who mistook the prosomal appendages for the barbels of a catfish of the genus *Silurus*. In 1831 Scouler described, but did not name, a large peculiar eurypterid from the Lower Carboniferous of Scotland, which in 1836 was redescribed and named by Hibbert (*Hibbertopterus scouleri*). In New York, another *Eurypterus* was discovered from the Silurian and described by Harlan in 1836 (*Eurypterus remipes lacustris*). Agassiz in 1839 mistook the squamous sculpturing of some indefinite fragments of eurypterids from the Silurian of the Welsh Borderland for the remains of a fish which he named *Pterygotus problematicus*. The confusion attending this determination did not last long as the great naturalist was able to correct the mistake in 1844 and to recognize the arthropod nature of *Pterygotus* from better material collected by Charles Lyell in the Old Red sandstone of Scotland (*Pterygotus anglicus*).

On the continent G. Fischer de Waldheim in 1839 described an *Eurypterus* (*Eurypterus remipes tetragonophthalmus*) from the Silurian of Podolia, and Jordan & Meyer in 1854 revealed the presence of an eurypterid in the Upper Carboniferous of Saarbrucken (*Adelophthalmus granosus*). Almost at the same time, in 1855, Reuss described another Upper Carboniferous form from Bohemia (*Adelophthalmus imhofi*). In 1852 Salter described under the name *Pterygotus problematicus* Agassiz, a chelicera of a large eurypterid from the Silurian of the Welsh Borderland. In 1855 he described a *Eurypterus* (*E. cephalaspis*) from the Downtonian of Westmoreland and followed in 1856 with the description of several forms from the Silurian of Scotland (*Erettopterus bilobus, Hughmilleria lanceolata* and *Slimonia acuminata*) and a species from the Silurian of the Welsh Borderland (*Hughmilleria banksii*).

It was against this meagre backgound, involving barely a dozen known forms, that Huxley & Salter published their monograph in 1859 and during the same year Salter published a short paper on the Eurypterida of the Welsh Borderland. The eurypterids used in these important papers were collected mainly by other geologists, among them an active group known as the Ludlow Geologists. Among this group and from nearby areas, the most articulate and avid collectors were Robert Lightbody, R. W. Banks, Alfred Marston, G. Cocking, P. B. Brodie, J. Harley, Col. Colvin, R. Gibbs and J. E. Gray whose collections, made prior to 1859, represent an unusual array of eurypterid material which finally was deposited mainly in the collections of the British Museum (Natural History) and the Geological Survey and Museum, London, England. Later, during the period of 1866 to 1878, these collections were reviewed by Henry Woodward and formed part of the material reported in his monograph of those years. The review presented here is based mainly on these old collections, and it is a pleasure to report that the collections still yield hitherto unknown morphological details and considerable new taxonomic information. In total, approximately four hundred specimens are present in the collections studied, including the material recently collected by Robert H. Denison and in the Chicago Natural History Museum.

The preservation of the eurypterids of the Welsh Borderland varies as they occur in dolomites, sandstones and shales, but overall the preservation is good. Most specimens occur as fragments, some up to 10 cm. in diameter, although the greater part are considerably less in size. Very few whole, or articulated, specimens are present. In the shales and dolomites some of the specimens are preserved well enough to reveal the original coloration (see discussion of *Erettopterus spatulatus* and *Eurypterus cephalaspis*) although such specimens are rare. Specimens found in sandstone or dolomitic sediments retain original convexity.

The complete list of the Eurypterida of the Welsh Borderland is as follows (including additions and deletions proposed in this paper):

Wenlock beds:

1. *Mixopterus* (?) sp. (this report)

2. *Pterygotus* (*Pterygotus*) *grandidentatus* Kjellesvig-Waering, n. sp.

Middle Ludlow (Mocktree shales):

1. *Carcinosoma punctatum* (Salter)
2. *Erettopterus* (*Erettopterus*) *marstoni* Kjellesvig-Waering, n. sp.
3. *Pterygotus* (*Pterygotus*) *arcuatus* Salter
4. *Salteropterus* (?) *longilabium* Kjellesvig-Waering, n. sp.

Upper Ludlow:

1. *Carcinosoma harleyi* Kjellesvig-Waering, n. sp.
2. *Erettopterus* (*Erettopterus*) sp. (this report)
3. *Erettopterus* (*Truncatiramus*) *gigas megalodon* Kjellesvig-Waering, n. ssp.
4. *Pterygotus* (*Pterygotus*) *denticulatus* Kjellesvig-Waering, n. sp.
5. *Pterygotus* (*Pterygotus*) *lightbodyi* Kjellesvig-Waering, n. sp.

Downtonian:

1. *Carcinosoma* (?) sp. Kjellesvig-Waering, 1951
2. *Dolichopterus bulbosus* Kjellesvig-Waering, n. sp.
3. *Erettopterus* (*Erettopterus*) *brodiei* Kjellesvig-Waering, n. sp.
4. *Erettopterus* (*Erettopterus*) *spatulatus* Kjellesvig-Waering, n. sp.
5. *Erettopterus* (*Truncatiramus*) *gigas gigas* (Salter)
6. *Eurypterus cephalaspis* Salter
7. *Hughmilleria* (*Hughmilleria*) (?) *acuminata* (Salter)
8. *Hughmilleria* (*Hughmilleria*) *banksii* (Salter)
9. *Hughmilleria* (*Nanahughmilleria*) *pygmaea* (Salter)
10. *Marsupipterus sculpturatus* Caster & Kjellesvig-Waering
11. *Mixopterus* sp. Kjellesvig-Waering, 1951
12. *Parahughmilleria salteri* Kjellesvig-Waering, n. sp.
13. *Pterygotus* (*Pterygotus*) *ludensis* Salter
14. *Salteropterus abbreviatus* (Salter)
15. *Slimonia* (?) *stylops* (Salter)
16. *Stylonurus megalops* (Salter)
17. *Tarsopterella* sp. Kjellesvis-Waering, 1951

A checklist of the Eurypterida of the Welsh Borderland, including the results of this paper and in alphabetical order, follows below. The name originally used is placed in the left hand column, whereas the recommended usage is on the right:

TABLE 1—CHECKLIST OF EURYPTERIDA OF THE WELSH BORDERLAND

Name previously used (including this paper):	Recommended usage:
Carcinosoma harleyi Kjellesvig-Waering, n. sp.	*Carcinosoma harleyi* Kjellesvig-Waering, n. sp.
Carcinosoma punctatum (Salter)	*Carcinosoma punctatum* (Salter)
Carcinosoma sp. Kjellesvig-Waering, 1951	*Carcinosoma* (?) sp. Kjellesvig-Waering
Carcinosoma (?) sp. Kjellesvig-Waering	*Carcinosoma* (?) sp. Kjellesvig-Waering
Dolichopterus bulbosus Kjellesvig-Waering, n. sp.	*Dolichopterus bulbosus* Kjellesvig-Waering, n. sp.
Erettopterus (*Erettopterus*) *brodiei* Kjellesvig-Waering, n. sp.	*Erettopterus* (*Erettopterus*) *brodiei* Kjellesvig-Waering, n. sp.
Erettopterus (*Erettopterus*) *marstoni* Kjellesvig-Waering, n. sp.	*Erettopterus* (*Erettopterus*) *marstoni* Kjellesvig-Waering, n. sp.
Erettopterus (*Erettopterus*) *spatulatus* Kjellesvig-Waering, n. sp.	*Erettopterus* (*Erettopterus*) *spatulatus* Kjellesvig-Waering, n. sp.
Erettopterus Erettopterus sp. (this report)	*Erettopterus* (*Erettopterus*) sp. Kjellesvig-Waering
Erettopterus (*Truncatiramus*) *gigas gigas* (Salter)	*Erettopterus* (*Truncatiramus*) *gigas gigas* (Salter)
Erettopterus (*Truncatiramus*) *gigas megalodon* Kjellesvig-Waering, n. ssp.	*Erettopterus* (*Truncatiramus*) *gigas megalodon* Kjellesvig-Waering, n. ssp.
Eurupterus abbreviatus Salter	*Salteropterus abbreviatus* (Salter)
Eurypterus acuminatus Salter	*Hughmilleria* (*Hughmilleria*) (?) *acuminata* (Salter)
Eurypterus brodiei Woodward	*Eurypterus cephalaspis* Salter
Europterus brodiei (*pars*) Woodward 1871, 1872	*Hughmilleria* (*Hughmilleria*) *banksii* (Salter)
Eurypterus cephalaspis Salter	*Eurypterus cephalaspis* Salter
Eurypterus linearis Salter	*Eurypterus cephalaspis* Salter
Eurypterus megalpos Salter	*Stylonurus megalops* (Salter)
Eurypterus punctatus (Salter)	*Carcinosoma punctatum* (Salter)
Eurypterus pygmaeus Salter	*Hughmilleria* (*Nanahughmilleria*) *pygmaea* (Salter)
Eurypterus pygmaeus (*pars*) Salter (Banks, 1856)	*Eurypterus cephalaspis* Salter
Eurypterus pygmaeus Salter (Salter 1859, *pars*)	*Parahughmilleria salteri* Kjellesvig-Waering, n. sp.
Eurypterus pygmaeus Salter? (Powrie, 1864)	*Hughmilleria* (*Nanahughmilleria*) *pygmaea* (Salter)
Eurypterus pygmaeus Salter (Woodward, 1871)	*Hughmilleria* (*Nanahughmilleria*) *banksii* (Salter)
Eurypterus cf. *pygmaeus* Salter (Schlüter, 1881)	*Parahughmilleria salteri* Kjellesvig-Waering, n. sp.
Eurypterus pygmaeus Salter? (Salter, 1859b)	*Palaeophonus lightbodyi* Kjellesvig-Waering
Eurypterus (?) sp. (this report)	*Eurypterus* (?) sp. Kjellesvig-Waering

(*Table 1 continued on next page*)

TABLE 1—*Continued*)

Name previously used (including this paper):	Recommended usage
Eusarcus punctatus (Salter)	*Carcinosoma punctatum* (Salter)
Himantopterus banksii Salter	*Hughmilleria* (*Hughmilleria*) *banksii* (Salter)
Homalonotus (?) *cephalaspis* Salter	*nomen nudum*
Hughmilleria acuminata (Salter)	*Hughmilleria* (*Hughmilleria*) (?) *acuminata* (Salter)
Hughmilleria (*Hughmilleria*) (?) *acuminata* (Salter)	*Hughmilleria* (*Hughmilleria*) (?) *acuminata* (Salter)
Hughmilleria banksii (Salter)	*Hughmilleria* (*Hughmilleria*) *banksii* (Salter)
Hughmilleria (*Hughmilleria*) *banksii* (Salter)	*Hughmilleria* (*Hughmilleria*) *banksii* (Salter)
Hughmilleria linearis (Salter)	*Eurypterus cephalaspis* Salter
Hughmilleria (?) *pygmaea* Salter (Størmer, 1936)	*Parahughmilleria salteri* Kjellesvig-Waering
Hughmilleria pygmaeus (Salter)	*Hughmilleria* (*Nanahughmilleria*) *pygmaea* (Salter)
Hughmilleria (*Nanahughmilleria*) *pygmaea* (Salter)	*Hughmilleria* (*Nanahughmilleria*) *pygmaea* (Salter)
Marsupipterus sculpturatus Caster & Kjellesvig-Waering	*Marsupipterus sculpturatus* Caster & Kjellesvig-Waering
Mixopterus sp. Kjellesvig-Waering (1951)	*Mixopterus* sp. Kjellesvig-Waering
Mixopterus (?) sp. (this paper)	*Mixopterus* (?) sp. Kjellesvig-Waering
Pterygotus arcuatus Salter	*Pterygotus* (*Pterygotus*) *arcuatus* Salter
Pterygotus banksii (Salter)	*Hughmilleria* (*Hughmilleria*) *banksii* (Salter)
Pterygotus banksii Salter (*pars*) (Woodward, 1866–1878)	*Erettopterus* (*Erettopterus*) *spatulatus* Kjellesvig-Waering, n. sp.
Pterygotus banksii Salter (*pars*) (Salter, 1859)	*Erettopterus* (*Erettopterus*) *spatulatus* Kjellesvig-Waering, n. sp.
Pterygotus (*Erettopterus*) *banksii* (Salter)	*Hughmilleria* (*Hughmilleria*) *banksii* (Salter)
Pterygotus (*Erettopterus*) *gigas* Salter	*Erettopterus* (*Truncatiramus*) *gigas gigas* (Salter)
Pterygotus gigas Salter (Salter, 1859, pl. 9, fig. 13)	*Pterygotus* (*Pterygotus*) *ludensis* Salter
Pterygotus ludensis Salter	*Pterygotus* (*Pterygotus*) *ludensis* Salter
Pterygotus ludensis Salter (Salter, 1859, pl. 9, fig. 18, pl. 12, figs. 1–3)	*Erettopterus* (*Truncatiramus*) *gigas gigas* Salter
Pterygotus problematicus Agassiz	*nomen vanum*
Pterygotus problematicus Salter (1852)	*Erettopterus* (*Truncatiramus*) *gigas megalodon* Kjellesvig-Waering, n. ssp.
Pterygotus problematicus Strickland & Salter (1852)	*Erettopterus* (*Truncatiramus*) *gigas megalodon* Kjellesvig-Waering, n. ssp.
Pterygotus (*Pterygotus*) *arcuatus* Salter	*Pterygotus* (*Pterygotus*) *arcuatus* Salter
Pterygotus (*Pterygotus*) *denticulatus* Kjellesvig-Waering, n. sp.	*Pterygotus* (*Pterygotus*) *denticulatus* Kjellesvig-Waering, n. sp.
Pterygotus (*Pterygotus*) *grandidentatus* Kjellesvig-Waering, n. sp.	*Pterygotus* (*Pterygotus*) *grandidentatus* Kjellesvig-Waering, n. sp.
Pterygotus (*Pterygotus*) *lightbodyi* Kjellesvig-Waering, n. sp.	*Pterygotus* (*Pterygotus*) *lightbodyi* Kjellesvig-Waering, n. sp.
Pterygotus (*Pterygotus*) *ludensis* Salter	*Pterygotus* (*Pterygotus*) *ludensis* Salter
Pterygotus punctatus Salter	*Carcinosoma punctatum* (Salter)
Pterygotus punctatus Salter (Salter, 1859, pl. XI, fig. 4)	*Salteropterus* (?) *longilabium* Kjellesvig-Waering, n. sp.
Parahughmilleria salteri Kjellesvig-Waering, n. sp.	*Parahughmilleria salteri* Kjellesvig-Waering, n. sp.
Pterygotus stylops Salter	*Slimonia* (?) *stylops* Salter
Pterygotus (?) *stylops* Salter (Woodward, 1866-1878)	*Slimonia* (?) *stylops* Salter
Pterygotus sp. Kjellesvig-Waering, 1951	*Erettopterus* (*Erettopterus*) *spatulatus* Kjellesvig-Waering, n. sp.
Salteropterus abbreviatus (Salter)	*Salteropterus abbreviatus* (Salter)
Salteropterus (?) *longilabium* Kjellesvig-Waering, n. sp.	*Salteropterus* (?) *longilabium* Kjellesvig-Waering, n. sp.
Slimonia (?) *stylops* Salter	*Slimonia* (?) *stylops* Salter
Stylonurus megalops (Salter)	*Stylonurus megalops* (Salter)
Stylonurus megalops Salter (*pars*) (Salter, 1859, pl. 10, figs. 13–14)	*Hughmilleria* (*Hughmilleria*) *banksii* (Salter)
Stylonurus punctatus (Salter)	*Carcinosoma punctatum* (Salter)
Tarsopterella (?) sp. Kjellesvig-Waering, 1951	*Tarsopterella* (?) sp. Kjellesvig-Waering, 1951
Tarsopterus (?) sp. Kjellesvig-Waering, 1951	*Tarsopterella* (?) sp. Kjellesvig-Waering, 1951

Pterygotus taurinus Salter, 1868, is omitted from the above list because the species is apparently from the Devonian (R. Baker, personal communication, 1959). The species is, however, composite, and consists of three distinct eurypterids. There does not seem much doubt that the large carapace is the main part of the fossil and the part which Salter probably intended should represent *P. taurinus*, as at the time the carapace was considered of primary importance over such structures as the chelicera, prosomal appendages, and telson. The carapace and chelicera represent a large *Pterygotus* (*Pterygotus*) remarkably like *Pterygotus* (*Pterygotus*) *anglicus* Agassiz. The type specimens, however, have been lost, and the writer does not refer *P.* (*P.*) *taurinus* to the latter until there is verification from the type specimens, particularly the chelicera.

The leg reveals a species which obviously is not a pterygotid and is herein referred, with doubt, to the Carcinosomatidae, and for convenience as *Carcinosoma* (?) sp., although said genus is unknown from Devonian beds. The telson also is not a *Pterygotus* but an *Erettopterus* which here is referred to as *Erettopterus* (*Erettopterus* ?) sp.

The above specimens are highly important but unfortunately have been misplaced. The last record of these specimens appears in Woodward 1866–78, p. 76, who states that all were in the cabinet of Dr. McCullough of Abergavenny.

It should be stressed that the reason for the greater number of species of eurypterids in the Downtonian, over those in the underlying Ludlow, is due to other factors rather than as a burst of new life which might signify a hiatus heralding the beginning of a new period and, thus, forming a convenient boundary between the Silurian and Devonian periods. The species of eurypterids known from the overlying Devonian beds are even less in number than those found in the Ludlow. So far as the incomplete record of the eurypterids indicate, no hiatus between the Ludlow and Downtonian is discernible but a rather good case can be made that the Downtonian eurypterids have little or no relationship to the overlying Devonian Old Red eurypterids, but do reveal considerable affinities with the Ludlow.

The greater number of eurypterids in the Downtonian is caused by the latter's being a thick series that contains several eurypterid zones, each of which contains its characteristic number of species, whereas the underlying beds, so far, are mainly represented each by a single eurypterid zone. Apart from this, the greater number of eurypterids present in the Downtonian is also caused by facies considerations in that the eurypterids of the Downtonian lived in more quiet waters and in muddy bottoms, such as the shales of the Temeside, which were ideal for their preservation. Furthermore, the Downtonian eurypterids belong to the Hughmilleriidae-Stylonuridae ecological phase (see below) which is characterized by a greater variety of forms in contrast to the other phases. The eurypterids of the Upper Ludlow, the Middle Ludlow (Mocktree shale) and Wenlock were preserved in a more open marine environment and consequently, mainly the harder parts, such as pterygotid chelicerae and carcinosomatid appendages, were preserved. These beds probably were not deposited in as sheltered or quiet waters as those of parts of the Downtonian. Unlike the Downtonian, the thin films of eurypterid integument are not common, a condition probably caused by destruction by currents or wave action, or indeed, they could well have served as a source of food to the many marine animals present in the Ludlow and Wenlock shallow seas. In the Downtonian, indications of other animals are far less common.

It is interesting to note that among the eurypterids, certain genera and families occupied distinct habitats in the Silurian and all were not dependent on one environment, as has been advanced by some authors. In a general way, three more or less distinct ecological environments are discernible in the Silurian. It is known that all of the Carcinosomatidae discovered to date have been found only in marine beds. In the Welsh Borderland, *Carcinosoma punctatum* occurs on the same bedding plane as bryozoans, starfishes, articulate brachiopods, linguloids and trilobites. Above all, *Carcinosoma* commonly occurs with pterygotids. The Carcinosomatidae-Pterygotidae phase appears to be the most marine of the eurypterid faunas. In its best development, this possible cycle generally comprises practically only pterygotids, which commonly is referred to as "*Pterygotus* beds" in the litera-

ture. Another possible ecological phase of the eurypterids in the Silurian is marked by the family Eurypteridae. Whenever genera of this family are found in abundance, as for example, *Eurypterus* and *Erieopterus*, other forms are rare, although pterygotids, carcinosomatids and dolichopterids are generally present in varying numbers, but never commonly. The main constituents of this phase are the Eurypteridae. These too, in the Silurian, are of marine origin but indicating more sheltered or less open, quiet, waters, perhaps as found in bays, estuaries, or lagoons. The lithofacies generally are the fine grained, magnesium carbonate muds which formed the common eurypterid-bearing beds known as "waterlimes."

The last of the possible recognizable ecological phases in the Silurian which can be discerned at present is characterized by genera of the families Hughmilleriidae and Stylonuridae. These generally occur in sandy and argillaceous bottoms, very rarely calcareous, or dolomitic, and commonly associated with very few other fossils. The streamlined shape of *Hughmilleria* and *H.* (*Nanahughmilleria*) indicates forms well suited for movement against currents but it also indicates nothing more than a more active swimmer. This zone is less likely to be marine than the Eurypteridae phase; perhaps the environment in the Silurian was the more brackish part of bays, and estuaries.

The three possible ecological environments in the Silurian therefore may be known as (1) the Carcinosomatidae-Pterygotidae, (2) the Eurypteridae and (3) the Hughmilleriidae-Stylonuridae phases. It appears that zone 1 is the most marine and that zone 3 is progressively less marine, whereas zone 2 is intermediate between the two. There is, of course, intermingling of these three phases and indeed it is interesting to note that the two more marine phases seem to be the ones more commonly mixed. Among the better known world Silurian eurypterid assemblages, the Buffalo, Herkimer, and Manlius faunas in New York, the Put-in-Bay fauna in Ohio and the Oesel fauna belong to the Eurypteridae phase. The middle Vernon fauna in New York, and the lower Vernon (*Carcinosoma vaningeni* zone: According to Willard P. Leutze, personal communication December 19, 1959, the type locality of *Carcinosoma vaningeni* is not in the Camillus shale but is in the Vernon shale and older than the Pittsford fauna. Ruedemann, 1916, p. 114, considers the Pittsford fauna to be equivalent to the type locality of *C. vaningeni*), the Middle Ludlow, Mocktree shale fauna in England, the Lesmahagow fauna in Scotland, and the Bohemian Budňany and Lochkov faunas indicate the Carcinosomatidae-Pterygotidae phase. The Shawangunk and part of the Pittsford-lower Vernon faunas of New York, the Ringerike Downtonian, the Pentland Hills fauna of Scotland, and the Downtonian of the Welsh Borderland clearly indicate the Hughmilleriidae-Stylonuridae phase. In regard to the Pittsford fauna, it is probable that both the Eurypteridae phase and Hughmilleriidae-Stylonuridae phase occur in separate horizons.

The writer believes that as more faunas are known, other cycles or ecological phases may become known. The three indicated above, however generalized, seem to be too persistent in the Silurian not to be indicative of some environmental or ecological condition.

A comparison of the eurypterids of the Downtonian to the overlying Devonian and the underlying Ludlovian eurypterids clearly reveals a far closer relationship with the Ludlow than with the overlying Old Red species. The genera *Eurypterus*, *H.* (*Hughmilleria*), *H.* (*Nanahughmilleria*), *Mixopterus*, *Carcinosoma* and *Erettopterus* (*Erettopterus*) are known exclusively from Silurian strata. Furthermore, the species of pterygotids all show much closer relationship to Ludlovian than Old Red species. In one case, *Erettopterus* (*T.*) *gigas gigas* differs only in minor details from the Ludlovian *E.* (*T.*) *gigas megalodon* and the species *Pterygotus* (*Pterygotus*) *arcuatus* of the Middle Ludlow, *P. P. lightbodyi* of the Upper Ludlow and *P. P. ludensis* of the Downtonian reveal close relationship which, when other parts of these eurypterids are known, may show that each is but a temporal subspecies. At any rate, the affinities of these forms seem readily apparent. Therefore, at least on the basis of the eurypterid fauna, there exists no evidence that the Downtonian should be considered as part of the Devonian but some evidence does exist to suggest that it should

be retained within the Silurian.

The criterion for the identification of pterygotids is an important consideration. All too often, any fragment of the characteristic, scale-like integument is identified as *Pterygotus problematicus* Agassiz or *Pterygotus anglicus* Agassiz not merely in England and Scotland but also in North America and continental Europe. All pterygotids, regardless of genus, have the same type of scale-like markings and it is highly improbable, if not an impossibility, to determine such fragments to species level on that basis. The integument, or indeed the entire tergites or sternites for that matter, merely indicates a pterygotid. In the literature, there are numerous examples of these faulty determinations with the result that the ranges of some of the pterygotids involved have been extended until that particular species is of little value for correlative purposes. This is particularly unfortunate as the pterygotids, when properly determined, are excellent index fossils.

The two species which have led to more faulty determinations are the two mentioned above. In regard to *Pterygotus problematicus*, this name has been found to be a *nomen vanum* (see page 812) and discarded. In regard to *Pterygotus* (*P.*) *anglicus* Agassiz it should be stated that there exists no proper documentation in the form of figures to support its presence outside of Scotland. References, and they are numerous, of the species occurring elsewhere in the British Isles and France are based on undiagnostic fragments which signify nothing more than the presence of a pterygotid and not necessarily the definite and easily recognizable *P.* (*P.*) *anglicus*. The writer does not doubt that *P.* (*P.*) *anglicus* does not occur on the Continent and, in particular, the Welsh Borderland; nevertheless, to date no evidence has been presented that such is the case.

In this respect, it may be well to stress that the large pterygotids are difficult to identify inasmuch as the diagnostic parts actually make up a small part of the animal. It may be generalized that the chelicera and telson are of basic importance in identification, and whenever possible, one should attempt to base their determinations on those parts. Of secondary importance are the carapace, the coxae of the legs, gnathobases, metastoma, etc. Unfortunately, the parts most recovered of the pterygotids are the tergites and sternites, or fragments thereof, which indicate only the family Pterygotidae, but not the generic or specific determinations.

The above applies to the Pterygotidae only. In regard to other Eurypterida, it is of primary diagnostic importance to have the carapace, operculum, or any of the prosomal appendages. Of secondary importance may be included the metastoma, telson and coxae of these eurypterids. Some eurypterids are so peculiarly marked that identification can be fairly certain by the ornamentation only, but such cases are uncommon. In regard to the Eurypteracea, the swimming leg paddle is of particular diagnostic importance.

ACKNOWLEDGMENTS

The writer wishes to convey his thanks to the Trustees of the British Museum (Natural History), the Keeper of the Invertebrate Paleontology Department, Dr. E. I. White, and in particular, Mr. R. Baker of the same Department who have been of invaluable help to the writer not only in kindly furnishing collections, casts and photographs but in giving the author data on certain stratigraphic matters and also instigating search for several "lost" types. To Dr. C. J. Stubblefield, of the Geological Survey and Museum, the writer is also greatly indebted for his kind opinion on stratigraphic matters and for furnishing part of the collections herein reported. Acknowledgment is also given to Dr. J. D. D. Smith of the Geological Survey and Museum for part of the collections. He wishes also to thank Dr. F. W. Shotton of Birmingham University who kindly loaned the writer a valuable and recently assembled collection of eurypterids from the Welsh Borderland. To Dr. Eugene S. Richardson, Jr., and Dr. Robert H. Denison of the Chicago Natural History Museum, thanks are also due for the loan of collections. To Dr. Richardson the writer is particularly indebted for his valued opinion on certain taxonomic matters. The responsiblity for the opinions advanced here, however, are entirely the writer's and should not be attributed to others if incorrectly interpreted. Acknowledgment is also made for the excellent stereoscopic pairs,

and the photograph reproduced on Plate 96, figure 1, which were sent to the writer by Mr. A. G. Brighton and Mr. C. L. Forbes, Curator and Assistant Curator of the Sedgwick Museum, Cambridge University.

Class MEROSTOMATA Dana, 1852
Order EURYPTERIDA Burmeister, 1843
Superfamily EURYPTERACEA Burmeister, 1845
Genus HUGHMILLERIA Sarle, 1903

Within the limits of what is commonly considered the genus *Hughmilleria* Sarle 1903 are a number of species which generally are questionably referred to the genus. The discovery of the operculum in the form described on page 807 as *Parahughmilleria* excludes some of the more questionable *Hughmilleriae*. However, the problem does not end there as there are a number of forms, exemplified by *H. norvegica*, *H. lanceolata*, etc., which actually are quite far removed from the characteristics embodied by the genotype *Hughmilleria socialis* Sarle. These forms are characterized by having reniform eyes, well away from the margin of the carapace, instead of having large ovoid eyes which are marginally placed on the carapace. This is a fundamental departure; in this writer's opinion it is of phylogenetic and taxonomic importance (see "Remarks" under genus *Parahughmilleria*). The writer, therefore, proposes that a new subgenus, *Nanahughmilleria*, be established to accommodate the forms of which *H. norvegica* is characteristic. It is possible that the differences cited here may eventually be considered of generic rather than subgeneric importance.

The writer proposes the following classification:

As defined here, *Hughmilleria* (*Hughmilleria*) is known from the Ordovician and Silurian, whereas *H.* (*Nanahughmilleria*) is known only from the Silurian.

Genus HUGHMILLERIA Sarle, 1903
Genotype: *Hughmilleria socialis* Sarle

Carapace with eyes marginal or anteriorly located; body lanceolate, metastoma ovate; chelicera comparatively large, walking legs increasing in length posteriorly, undifferentiated; swimming leg comparatively large and long; male genital appendage very long; female, short; telson lanceolate, slightly carinated dorsally; surface sculpturing ranging from smooth to semilunar scales and with transverse folds.

Distribution.—Europe and North America.

Stratigraphic Range.—Ordovician and Silurian.

Subgenus HUGHMILLERIA Sarle, 1903
Subgenotype: *Hughmilleria socialis* Sarle

Hughmilleriae of small size with large ovoid eyes marginally located on the carapace.

Recognized species:

H. (*Hughmilleria*) (?) *acuminata* (Salter)—Silurian; England.
H. (*Hughmilleria*) *banksii* (Salter)—Silurian; England.
H. (*Hughmilleria*) *kilfoylei* Ruedemann—Ordovician; New York.
H. (*Hughmilleria*) (?) *linguata* Clarke & Ruedemann—Ordovician; New York.
H. (*Hughmilleria*) *prisca* Ruedemann—Ordovician; New York.
H. (*Hughmilleria*) *shawangunk* Clarke—Silurian; New York.
H. (*Hughmilleria*) *socialis* Sarle—Silurian; New York.
H. (*Hughmilleria*) (?) *uticana* Ruedemann—Ordovician; New York.

Subgenus NANAHUGHMILLERIA Kjellesvig-Waering, n. subgen.
Subgenotype: *Hughmilleria norvegica* (Kiaer)

Hughmilleriae of small size with small reniform eyes intramarginally located on the carapace.

Recognized species:

H. (*Nanahughmilleria*) *conica* (Laurie)—Silurian; Scotland.
H. (*Nanahughmilleria*) *lanceolata* (Salter)—Silurian; Scotland.
H. (*Nanahughmilleria*) *norvegica* (Kiaer)—Silurian; Norway.
H. (*Nanahughmilleria*) *patteni* Størmer—Silurian; Oesel.
H. (*Nanahughmilleria*) (?) *prominens* (Hall)—Silurian; New York.
H. (*Nanahughmilleria*) *pygmaea* (Salter)—Silurian; England.
H. (*Nanahughmilleria*) *trigona* (Ruedemann) Silurian; New York.

Hughmilleria (?) *lata* Størmer, a problematical form, should be possibly referred to

the Dolichopteridae as *Dolichopterus* (?) *latus* Størmer.

HUGHMILLERIA (HUGHMILLERIA) (?) ACUMINATA (Salter)
Pl. 94, fig. 3; pl. 95, fig. 9; text-fig. 1, fig. 20

Eurypterus acuminatus SALTER, 1859, p. 233–234, pl. 10, fig. 17 (not fig. 19); BIGSBY, 1859, p. 321; WOODWARD, 1864, p. 107; ——, 1872 (1866–1878), p. 146–147, pl. 28, fig. 13 (not 15); MARSTON, 1870, p. 409; WOODWARD, 1871, p. 261; ——, 1877, p. 64; ETHERIDGE, 1888, p. 52; ELLES & SLATER, 1906, p. 220; O'CONNELL, 1916, p. 38; DIENER, 1924, p. 15; KING, 1934, p. 563.

Hughmilleria acuminata KJELLESVIG-WAERING, 1951, p. 2.

Since its discovery and description in 1859, the species still remains an enigma. This very rare form is known only from two specimens, the holotype which is figured here on Pl. 95, fig. 9, and another specimen figured on Pl. 94, fig. 3, and Text-fig. 20. Unfortunately, the additional specimen is only part of a telson, and adds but little information to our knowledge.

Available for this study was the holotype. The specimen retains the inside of the ventral side of the telson with only the posterior portion of the dorsal side preserved. The dorsum of the posterior part is slightly but definitely carinated, making nearly a triangle in cross-section. The ventral side is far less carinated and only, approximately, in the posterior half and on the spike part and not the expanded area. Greatest length of the holotype is 41.2 mm. and greatest width is 14.7 mm. The crenato-serrate margin is well developed and is comprised of large scales along the periphery of the telson.

The species has been relegated to the genus *Hughmilleria* although the shape of the telson is considerably broader than in any other species. It does not appear to fit the generic characteristics of *Slimonia* as that genus has a sharp terminal spike developed, and not a serrated (triangular in section) termination. Of the two *Hughmilleriae* known that occur in the Downtonian, namely *H. banksii* (Salter) and *H. pygmaea* (Salter), only in the latter is the telson unknown. This species, however, is consistently much too small to have a telson of the size that characterizes *H.(?) acuminata*. It may well belong with the Downtonian and equally enigmatic form described by Salter as *Pterygotus(?) stylops*. The latter appears, to the present writer, however, to be closer to *Slimonia* than anything else. We can only await discovery of more specimens to determine the question.

Horizon and locality.—The holotype, No. 89404, is preserved in olive shale from the Downtonian at the railway cutting, Ludlow, Shropshire, collected by Robert Lightbody, 1858–59, whereas No. In 44575 is from the Downton sandstone at Ludford Lane, Ludlow, Shropshire, collected by A. Marston, about 1857.

Repository.—The holotype, No. 89404, is in the collections of the Geological Survey and Museum, London; No. In 44575 is in the collections of the British Museum (N. H.).

HUGHMILLERIA (HUGHMILLERIA) BANKSII (Salter)
Pl. 94, figs. 1,2

Himantopterus banksii SALTER, 1856, p. 32–33; 1856a, p. 266, foss. 66, fig. 1; BANKS, 1856, p. 99, figs. 5–6.

Pterygotus (*Erettopterus*) *banksii* SALTER, 1859, p. 51–53, pl. xii, figs. 22,24–29,31–35,41–44 (not 23,30,36–38,40,45–46); BIGSBY, 1859, p. 322; CLARKE & RUEDEMANN, 1912, p. 379; O'CONNELL, 1916, p. 47; DIENER, 1924, p. 10 (*pars*); STØRMER, 1936, p. 41.

Pterygotus banksii SALTER, 1859b, p. 540; ——, 1867, p. 239; MARSTON, 1870, p. 409; WOODWARD, 1871, p. 261; ——, 1872 (1866–1878), p. 72–74, pl. xvi, figs. 2,3,5,6 (not 4); SALTER, 1873, p. 189; WOODWARD, 1877, p. 67; ETHERIDGE, 1888, p. 66; SARLE, 1903, p. 1103; ELLES & SLATER, 1906, p. 220; KING, 1934, p. 563; STØRMER, 1934, p. 95.

Stylonurus megalops (*pars*) SALTER, 1859, pl. 10, figs. 13,14; BRODIE, 1869, p. 236; WOODWARD, 1872 (1866–1878), pl. 28, figs. 8,9.

Eurypterus brodiei (*pars*) WOODWARD, 1871, p. 262–263, figs. 2,3; ——, 1872, p. 162–163 (*pars*), fig. 51, (2,3).

Hughmilleria banksii STØRMER, 1934b, p. 83; ——, 1934a, (*pars*), p. 4; KJELLESVIG-WAERING, 1950, p. 228; ——, 1951, p. 4–14, pl. 1; pl. 2, figs. 1–5; text-fig. 1,2A,B.

Not *Hughmilleria* (*H.*) *banksii* (Salter)

Pterygotus banksii (Salter): SALTER, 1859a, pl. 12, figs. 23,30,36–38,40,45–46 (= *Erettopterus spatulatus* Kjellesvig-Waering).

Pterygotus banksii WOODWARD, 1872 (1866–1878), pl. 16, fig. 4 (= *Erettopterus spatulatus* Kjellesvig-Waering).

Hughmilleria banksii has had a complicated and confusing synonomy. This synonomy has previously been detailed (Kjel-

TEXT-FIG. 1—Details of Silurian eurypterid morphology.

(*Continued on page 799*)

1. *Hughmilleria* (*Nanahughmilleria*) *pygmaea* (Salter), ×2. The carapace, with ocelli reconstructed, from the Downton sandstone at Kington, Herefordshire, England. Specimen No. In 43775 in the British Museum (Natural History).
2. Same specimen from the side.
3. Same specimen from the front.
4. *Hughmilleria* (*Nanahughmilleria*) *pygmaea* (Salter), ×2. A well preserved carapace from the Downtonian at the railway cutting, Ludlow, Shropshire, England. Specimen No. 89383 in the Geological Survey and Museum, London.
5. Same specimen; a reconstruction of the undersurface of the carapace showing the ventral plates and doublures which were reflected through the dorsal shield. The lateral sutures of the epistoma were discernible; the other sutures were not clearly seen but their possible location is indicated.
6. *Parahughmilleria salteri* Kjellesvig-Waering, n. sp., ×2. A well preserved carapace, with ocelli reconstructed, from the Downton sandstone, Bradnor Hill, Kington, Herefordshire, England. A paratype, No. In 43776 in the British Museum (Natural History).
7. *Parahughmilleria salteri* Kjellesvig-Waering, n. sp., ×2. A well preserved carapace retaining original convexity. The ocelli have been reconstructed. This specimen is from the Downtonian at Ludford Lane, Ludlow, Shropshire, England, and is registered as No. 89420 in the Geological Survey and Museum, London.
8. Same specimen from the side to show the great convexity of the carapace.
9. Same specimen from the front. Compare with *H.* (*N.*) *pygmaea* in figure 3, a species commonly confused with *P. salteri.*
10. *Parahughmilleria salteri* Kjellevig-Waering, n. sp., ×2, paratype. The metasomal tergites and telson. This specimen has been figured by Salter (1859, pl. X, fig. 6) as the metasoma of *H.* (*N.*) *pygmaea.* It is from the Downtonian at the railway cutting, Ludlow, Shropshire, England and is registered as No. 89386 in the Geological Survey and Museum, London.
11. *Parahughmilleria salteri* Kjellesvig-Waering, n. sp., ×4, the holotype. Nearly complete operculum with female genital appendage and showing the lateral lobes. The specimen is from the Downtonian at the railway cutting, Ludlow, Shropshire, England, and is registered as No. 89391 in the Geological Survey and Museum, London.
12. *Parahughmilleria salteri.* Kjellesvig-Waering, n. sp., ×2, a paratype. Specimen retaining the carapace, complete mesosoma and the anterior tergites of the metasoma. It is the only specimen with retains part of the walking legs. The entire fourth walking leg is visible on the left side, and the third walking leg is present on the right side. Specimen No. 89387, in the Geological Survey and Museum, London.
13. *Eurypterus cephalaspis* Salter, ×2. An uncrushed carapace, preserved in sandstone, revealing the right side in an undistorted condition. This specimen gives the correct proportions of the carapace. The specimen is from the Downton sandstone at Onibury, 5 miles N.W. of Ludlow, Shropshire, registered as No. 89445 in the Geological Survey and Museum, London.
14. Same specimen from the front.
15. Same specimen from the side.
16. *Eurypterus cephalaspis* Salter, ×2. A nearly complete carapace; the right side is undistorted.The specimen is from the Downton sandstone at Ludford Lane, Ludlow, Shropshire, England and is registered as No. In 44574 in the British Museum (Natural History).
17. *Eurypterus cephalaspis* Salter, ×2. A nearly complete individual. The wide marginal rim is visible in part. The telson has been turned over to reveal the ventral carina. From the Temeside shale at the railway cutting, Ludlow, Shropshire, England and registered as No. In 44557 in the British Museum (Natural History).
18. *Eurypterus cephalaspis* Salter, ×2. The telson; a: the ventral side from the inside; b: the ventral carina from the inside; c: vestige of a dorsal carina (?); d: the dorsal side from the inside; e: the ventral carina. This specimen is the holotype of *Eurypterus linearis* Salter and was figured in the Q.J.G.S., London, 1859, vol. 15, pl. 10, fig. 16a. Salter also figured another telson on fig. 15 of the same plate, but this specimen was introduced as a variation. There is little doubt, therefore, that the specimen which he figured as 16a (fig. 18 here) was meant to embrace the characteristics of this species. Upper Ludlow (?), Ludford Lane, Ludlow, Shropshire, England, registered as No. 89426 in the Geological Survey and Museum, London.
19. *Eurypterus cephalaspis* Salter, ×2. Central part of the ventral side of the telson showing the prominent ventral carina. This specimen seems to be the specimen which Salter introduced as a variation of *Eurypterus linearis* (Q.J.G.S., London, 1859, vol. 15, pl. 10, fig. 15). Specimen is from the Downton sandstone, at Ludford Lane, Ludlow, Shropshire, England and registered as No. In 44576 in the British Museum (Natural History).
20. *Hughmilleria* (*Hughmilleria*) (?) *acuminata* (Salter), ×2. The telson showing indications of a median carina and the prominent serrations on the margins. Same specimen as pl. 1, fig. 3. From the Downton sandstone at Ludford Lane, Ludlow, Shropshire, England and registered as No. In 44575 in the British Museum (Natural History).
21. *Dolichopterus bulbosus* n. sp., ×2, holotype. The carapace, which is slightly distorted on the right side. Same specimen has been illustrated on Pl. 95, fig. 7. From the Temeside shale at the railway cutting, Ludlow, Shropshire, England and registered as No. In 44565 in the British Museum (Natural History).

lesvig-Waering 1951, p. 4–6) and will not be repeated here.

The species forms the most common element of the Downtonian eurypterid fauna. It has a marked preference for sandy sediments, and is found, rather rarely, in shales. It is a good index fossil for the Downtonian.

The streamlined carapaces are generally found separated from the rest of the body and these are commonly aligned in one direction (Plate 94, figure 1), very likely pointing in the direction of the current.

Measurements.—

Carapace: Specimen number:	Width at base:	Length:
89399	8.7 mm.	7.3 mm.
89479	12.2 mm.	10.5 mm.
89402	13.7 mm.	11.5 mm.
In 44566	17.3 mm.	16.5 mm.
89475	22.3 mm.	18.6 mm.
89471 (right)	incomplete	29.3 mm.
89471 (left)	incomplete	31.0 mm.

The largest specimen known is figured on Plate 94, figure 2, which has a carapace that measures 31.0 mm. in length. This is an uncrushed specimen. Specimens from Perton are wider but this width was caused by crushing. This specimen has eyes which are 8.5 mm. in length and 3.0 mm. in width. The specimen on the right side of the same slab has eyes which measure 7.5 mm. by 3.0 (est.) mm.

Horizon and locality.—The species is known only from the Downtonian of the Welsh Borderland. The writer had identified the following:

No. 89399: a prosoma preserved in sandy shale from the Downtonian at the railway cutting at Ludlow, Shropshire, collected by Robert Lightbody, 1858–1859.

No. 89400: the metasoma, including the telson, preserved in sandy shale. This is from the same locality and formation as the previous specimen. This was figured as the metasoma of *Stylonurus megalops* (Salter) by Salter, 1859, pl. 10, fig. 13, and was later figured by Woodward, 1872, pl. 28, fig. 8, who doubted Salter's determination but did not further identify the specimen.

No. 89402: a prosoma in sandy shale from the same locality, Wyatt-Edgell collection.

No. 89419; tergite from the Downtonian at Ludford Lane, Ludlow, Shropshire.

No. 89405: a crushed telson from the Downtonian at the railway cutting, Ludlow, Shropshire, collected by Robert Lightbody, 1858–1859. This was figured as the telson of *Stylonurus megalops* (Salter) by Salter, 1859, pl. 10, fig. 14, and Woodward, 1872, (1866–1878), pl. 28, fig. 9.

No. 89470: mesosomal tergite in sandstone; Downtonian at Bradnor Hill, Kington, Herefords. Collected by R. Gibbs.

No. 89471: two large carapaces in sandstone; Downtonian at Bradnor Hill, Kington, Herefords. Collected by R. Gibbs.

No. 89472: mesosomal tergite in sandy shale; Downtonian at Kington, Herefords.

No. 89474: large carapace in sandstone; Downtonian at Kington, Herefords.

No. 89475: carapace in sandstone; Downtonian at Kington, Herefords.

No. 89476: carapace in sandstone; Downtonian at Kington, Herefords.

No. 89477: carapace in sandstone; Downtonian at Kington, Herefords.

No. 89478: carapace in sandstone; Downtonian at Kington, Herefords.

No. 89479: carapace in sandstone: Downtonian at Bradnor Hill, Kington, Herefords; collected by R. Gibbs.

No. 89480: metastoma presented in sandstone from the Downtonian at Kington, Herefords.

No. 89481: metastoma preserved in sandstone from the Downtonian at Bradnor Hill, Kington, Herefords. This specimen was figured by Salter, 1859, pl. 12, fig. 31 as *Pterygotus banksii*.

No. 89492: metastoma preserved in sandstone from the Downtonian at Bradnor Hill, Kington, Herefords.

No. 89485: telson preserved in sandstone from the Downtonian at Kington, Herefords.

BU 17, a prosoma, and BU 27, a tergite, both preserved in sandstone, and from the Downton sandstone at Bradnor Hill, Kington, Herefords.

In 44571: a carapace preserved in sandstone, and In 44572, a large metastoma preserved in sandstone. Both are from the base of the Downton Sandstone at Ludford, Ludlow, Shropshire. Collected by Robert Lightbody about 1858.

In 44566: a carapace preserved in green shale; from the Temeside shales at the railway cutting, Ludlow, Shropshire. Collected by Robert Lightbody, about 1858.

In 44584: metasomal tergites and telson. This is the counterpart of specimen No. 89400, described above.

PE 4981: carapace preserved in green shale, Temeside (olive) shales at Tin Mill Race near Downton Castle, Herefords. Collected by Robert H. Denison. The writer has also identified numerous specimens from the basal part of the Downtonian at Perton, near Stoke Edith, Herefords (Kjellesvig-Waering, 1951, p. 4–14).

Repository.—Specimens No. 89399 to 89485 are in the collections of the Geological Survey and Museum, London; Nos. BU 17 and BU 27 are in the collections of the Geological Museum, Birmingham Univer-

sity, England; Nos. In 44571–72, In 44566 and In 44584 are in the British Museum and PE 4981 is in the Chicago Natural History Museum.

HUGHMILLERIA (NANAHUGHMILLERIA) PYGMAEA (Salter)

Pl. 95, fig. 8; text-fig. 1, figs. 1–5,27

Eurypterus pygmaeus BANKS, 1856, p. 99, pl. II, fig. 4a (*nomen nudum*).
Eurypterus pygmaeus SALTER, 1859, p. 232, pl. X, fig. 4; BIGSBY, 1859, p. 321; WOODWARD, 1864, p. 107; MARSTON, 1870, p. 409; WOODWARD, 1872 (1866–1878), p. 144–146, pl. XXVIII, fig. 5; ——, 1877, p. 65; ——, 1887, p. 481; ETHERIDGE, 1888, p. 53,145 (?); FRAIPONT, 1889, p. 57; CLAYPOLE, 1890, p. 260; ELLES & SLATER, 1906, p. 220; KIAER, 1911, p. 14; CLARKE & RUEDEMANN, 1912, p. 132; O'CONNELL, 1916, p. 41, fig. 28; DIENER, 1924, p. 19; KING, 1934, p. 563.
Eurypterus pygmaeus (?) POWRIE, 1864, p. 415; KING, 1934, p. 563.
Hughmilleria pygmaeus STØRMER, 1934, p. 83.
Hughmilleria (?) *pygmaea* STØRMER, 1936, p. 54 (British Downtonian form only).
Hughmilleria pygmaea KJELLESVIG-WAERING, 1950, p. 228; ——, 1958, p. 1142.

Not *Hughmilleria* (*Nanahughmilleria*) *pygmaea* (Salter)

Eurypterus pygmaeus SALTER *in* Banks, 1856, p. 99, pl. II, fig. 4b (= *Eurypterus cephalaspis* Salter).
Eurypterus pygmaeus SALTER, 1869, p. 232, pl. X, figs. 5,6,7,8 (= *Parahughmilleria salteri* Kjellesvig-Waering).
Eurypterus (?) possibly *E. pygmaeus* SALTER, 1859, p. 235, pl. 10, fig. 20 (= *Palaeophonus lightbodyi* Kjellesvig-Waering).
Eurypterus pygmaeus WOODWARD, 1872 (1866–1878), pl. 28, figs. 6–7 (= *Parahughmilleria salteri* Kjellesvig-Waering).
Eurypterus pygmaeus WOODWARD, 1871, p. 261 (= *Hughmilleria banksii* (Salter); see Kjellesvig-Waering, 1851, p. 6).
Eurypterus cf. *pygmaeus* SCHLÜTER, 1881, S210, u. 211 (= *Parahughmilleria salteri* (Kjellesvig-Waering).
Hughmilleria (?) *pygmaea* STØRMER, 1936, p. 53–54, pl. 1, fig. 3; pl. 7, fig. 4 (= *Parahughmilleri salteri* Kjellesvig-Waering).

Hughmilleria (*Nanahughmilleria*) *pygmaea* (Salter) is one of the best known eurypterids of the British Downtonian, although, unfortunately, the species was originally based on two separate species. Actually it was based on two separate species belonging to two different genera, as will be revealed here. The confusion began in 1856, when Salter apparently agreed to having the figures of his new *Eurypterus pygmaeus* in Banks' paper (Banks. 1856, pl. II, fig. 4a & b). There is no mention of the arrangement by either Banks or Salter; therefore, Banks' use of the name *Eurypterus pygmaeus* Salter must be considered *nomen nudum*.

The two specimens were from the Banks Collection (collected in 1855), and very likely are two specimens now in the collection of the Geological Survey and Museum and have been studied by the present writer. The first of these specimens (Banks, 1856, pl. II, fig. 4a), listed under No. 89483, is from the Downtonian at Kington, Herefordshire, and comprises a laterally compressed dorsal shield with the first five tergites of the mesosoma preserved. The eighth and ninth joints of the left swimming leg are present, and part of the metasoma is buckled and telescoped into the mesosoma. This specimen is preserved in sandstone as a counterpart and undoubtedly represents *Hughmilleria* (*N.*) *pygmaea* Salter. The other specimen (Banks 1856, pl. II, fig. 4b) comprises a nearly complete dorsal shield in which the left side is partly distorted, but overall the specimen retains original convexity. This specimen is registered as No. 89484 in the collection of the Geological Survey and Museum, and is not *H.* (*N.*) *pygmaea* Salter, but *Eurypterus cephalaspis* Salter, which at the time was known only from a single carapace from the Downtonian at Westmoreland.

Salter (1859a, p. 232, pl. X, figs. 4–8) finally described his new form as *Eurypterus pygmaeus* and included the above two specimens figured by Banks under the synonymy of his new species. Unfortunately, again two different species were included under *E. pygmaeus*. His fig. 4 properly represents *H.* (*N.*) *pygmaea* but the other figures (5–8) are an altogether different form which has herein been named *Parahughmilleria salteri*. Numerous specimens of both forms have been measured and studied and these reveal the marked difference between both species. Crushed or distorted specimens are very difficult to distinguish, but, briefly, the differences between uncrushed specimens of each are that the prosoma of *H.* (*N.*) *pygmaea* is much more elongated, having a ratio of 8.0 to 8.2:10, as compared to 6.8:10 in *Parahughmilleria salteri*, and the lateral

eyes are much larger and more elongated than in the latter. The former has a typical *Hughmillerian* doublure and therefore it would be expected that the operculum should be the same as in that genus. In contrast, *Parahughmilleria* has lateral lobes developed on the operculum, and therefore is an altogether different genus.

In summary, both the first specimens listed by Salter in Banks' (1856, fig. 4a) and in his own (1859, fig. 4) paper, represent the same species, *Hughmilleria pygmaea*, whereas the other specimens which commonly have been identified (see synonymy) as *H. pygmaea* properly belong to an altogether different form. The solution to the problem of what constitutes the species seems to be to retain the name *Hughmilleria pygmaea* (Salter) for the *Hughmilleria* and to rename a new species in honor of Salter for the species represented by his other specimens. This form has been named *Parahughmilleria salteri*. The first specimen figured by Salter (1859, pl. X, fig. 4) is herein designated as the lectotype of *Hughmilleria pygmaea* (Salter).

In the synonymy given above, it has not been possible, except where figures were given, to determine whether the author listed *H.* (*Nanahughmilleria*) *pygmaea* Salter, *Parahughmilleria salteri*, or even *Eurypterus cephalaspis* Salter. It is therefore necessary to note that previous to this paper, the stratigraphic range of *H.* (*N.*) *pygmaea* was not based on fact and it might be well to discount any previous listing that did not include figures. As such, *H.* (*N.*) *pygmaea* is known only from the Downtonian of the Welsh Borderland (see listing of specimens, page 31).

As emended here, *Hughmilleria* (*Nanahughmilleria*) *pygmaea* (Salter) has an elongated dorsal shield, narrowing gradually anteriorly and rounded along the anterior margin. The base is straight. The lateral eyes are narrow, reniform, and located anterior to the midsection of the dorsal shield. The ocelli are very small, located centrally on the dorsal shield and at a line connecting the base of the lateral eyes. A thin, narrow rim surrounds the dorsal shield.

A specimen (No. In 43775) from the Downton sandstone at Bradnor Hill, Kington, Herefordshire, from the R. W. Banks collection and figured here (Text-fig. 1, figs. 1,2,3) reveals the essential features of the dorsal shield, as the specimen is preserved in sandstone in an uncrushed condition and retains original convexity. This specimen has a dorsal shield which measures 11.5 mm. in length and 14.1 mm. in width, giving a length-width ratio of 8.2:10. The lateral eyes are 3.8 mm. in length, 1.6 mm. in width, and are located on the dorsal shield 3.3 mm. from the anterior margin, 4.9 mm. from the posterior margin, and 2.5 mm. from the lateral margin. They are 6.5 mm. apart at the posterior and 4.8 mm. apart at the anterior end of the eyes. The ocelli are not apparent but in Text-figure 1, fig. 1, are indicated in their rightful place.

Another well preserved specimen which reveals the characteristics of this species well is shown in Text-figure 1, figs. 4 and 5, and is from the R. Lightbody collection (No. 89383) collected at the Ludlow railway cutting, Ludlow, Shropshire. This specimen is preserved in greenish gray argillaceous sandstone as a dorsal impression, uncrushed, and retains original convexity. The carapace measures 8.5 mm. in length and 10.6 mm. in width, giving a length-width ratio of 8:10. The lateral eyes are 3.4 mm. in length, 1.1 mm. in width, are 3.0 mm. apart at the anterior end, and 4.3 mm. apart at the posterior edge. They are located on the dorsal shield 1.7 mm. from the anterior margin, 3.6 mm. from the posterior margin and 1.4 mm. from the lateral margin. The ocelli measure 0.2 mm. in diameter, are not located on any perceptible mound, and are placed almost centrally on the dorsal shield, being 4.3 mm. from the anterior margin and 4.0 mm. from the base.

Another specimen retaining the carapace only (No. 89397), collector unknown, is also from the Ludlow railway, Ludlow, Shropshire, and retains convexity but is partly distorted. The length is 8.8 mm. and the distorted width is 12.5 mm.

Another specimen (No. 89393) from the Ludlow railway section at Ludlow, Shropshire (from the Wyatt-Edgell collection made in 1868) is preserved in olive shale but is distorted and compressed laterally. This specimen retains the dorsal shield and first five tergites and part of the sixth tergite. The length of the prosoma is 5.7 mm., whereas the width measures 6.5 mm.,

giving a length-width ratio of 8.8:10, which is unusually long. However, this prosoma is obviously compressed laterally.

The first specimen figured by Salter (1859, pl. X, fig. 4) is herein designated as the lectotype. The specimen collected by Banks in 1856 from the Downtonian at Kington, Herefordshire (Banks, 1856, pl. 2, fig. 4a) is a counterpart preserved in sandstone and although retaining convexity is badly compressed laterally. However, the dorsal shield measures 12.7 mm. in length and 13.2 mm. in width, giving a length-width ratio of 9.6:10. This is, however, a dorsal shield which is badly compressed laterally, as the normal and uncompressed specimens range from 8:10 to 8.2:10.

The underside of the prosoma is not well known but the specimen (No. 89383) described above from the Ludlow railway reveals very faintly the typical *Hughmilleria* ventral plates (Text-figure 1, fig. 5).

The prosomal appendages are practically unknown. The chelicera is known, and this comprises small pincers (see Text-figure 2, fig. 27). The fingers are pointed and beveled at the inner edge. The specimen (lectotype) figured by Salter (1859, pl. X, fig. 4) retains a swimming leg which is elongated as in other *Hughmilleria*. Apart from these, Banks' specimen (No. 89483) retains the tarsus and transtarsus of the left swimming leg but these are too imperfectly preserved for description. No other legs are known.

The mesosoma is known from the lectotype and two other specimens described here (Nos. 89483 and 89393). These reveal that the first tergite is greatly reduced in length in comparison to the succeeding. Width measurements of the tergites are not possible due to compression and incompleteness; however, it appears that the mesosoma was rather narrow and possibly reached its greatest width at the third tergite. The measurements of the length of the tergites of two specimens described are as follows:

	Specimen 89483	Specimen 89393
1st tergite	1.0 mm.	0.5 mm.
2nd tergite	2.0 mm.	1.0 mm.
3rd tergite	2.0 mm.	1.1 mm.
4th tergite	2.5 mm.	1.5 mm.
5th tergite	2.5 mm.	1.5 mm.
6th tergite	3.0? mm.	incomplete

The underside of the mesosoma, as well as the entire metastoma, are unknown in this species. The telson is so far unknown. The known telsons of *H.* (*H.*)(*?*) *acuminata* Salter are much too large to fit any of the known specimens of *H.* (*N.*) *pygmaea*.

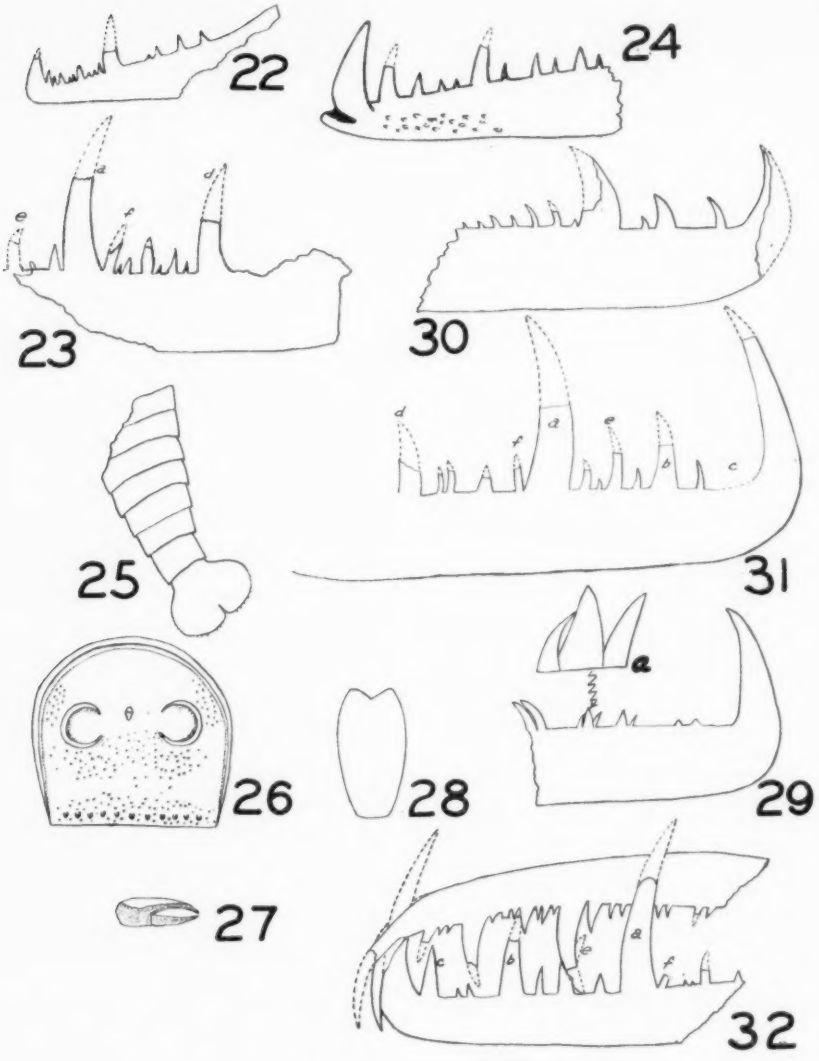
The dorsal shield is smooth. The mesosoma shows little ornamentation except parallel linear markings across the anterior part of the tergites. This comprises three to four linear markings. No scales have been noted. The posterior tergites of the mesosoma (No. In 44560) have the genal angles produced into pointed spurs which are striated.

Horizon and locality.—As emended and restricted here *Hughmilleria* (*Nanahughmilleria*) *pygmaea* (Salter) is known only from Downtonian beds of the Welsh Borderland, England. Specimen No. 89483 is from the Downton sandstone at Kington, Herefordshire; the lectotype, figured by Salter (1859, pl. X, fig. 4), is also from the same locality; No. In 43775 is from the Downton sandstone at Bradnor Hill, Kington; and specimens No. 89383, 89393, and 89397 are from the Downtonian section at the Ludlow railway, Ludlow, Shropshire, England. No. In 44560 is from the Temeside shale at the latter locality.

Repository.—Nos. In 43775 and In 44560 are in the collections of the British Museum (Natural History) and Nos. 89383, 89393, 89397 and 89483 are in the collection of the Geological Survey and Museum, London.

Remarks.—In comparison, *Hughmilleria* (*Nanahughmilleria*) *pygmaea* (Salter), as emended, resembles *Hughmilleria norvegica* (Kiaer) from the Downtonian beds of Ringerike, Norway, (Størmer 1934, p. 84) more than any other species of *Hughmilleria*. It differs from the latter mainly in having a more converging dorsal shield and in having the larger, longer lateral eyes located slightly farther away from the lateral and anterior margins of the prosoma.

In comparison with *Parahughmilleria salteri* Kjellesvig-Waering, the differences are numerous. The latter is a smaller species having a much wider dorsal shield which is nearly semicircular in contrast to the longer and more elliptical dorsal shield of *H. pygmaea*. Furthermore, the dorsal shield of *P. salteri* is unusually arched as compared with the more flattened shield of *H.* (*N.*) *pygmaea* (compare Text-figure 1, figs.2,3 with 8 and 9). The eyes of each species are



TEXT-FIG. 2—Details of Silurian eurypterid morphology.

22. *Erettopterus* (*Truncatiramus*) *gigas gigas* (Salter), ×1. The free ramus of the chelicera. This specimen has been figured by Salter, 1859, pl. 12, fig. 2 as *Pterygotus ludensis*. From the Downtonian at Ludlow, Shropshire, England and registered as No. 89410 in the Geological Survey and Museum, London.

23. *Pterygotus* (*Pterygotus*) *lightbodyi* Kjellesvig-Waering, n. sp., ×2. The central part of the free ramus of the chelicera. Tooth, e, has been added from counterpart specimen No. In 48421. From the

very different. In *P. salteri* they are small, short, reniform, and placed well within the margin of the dorsal shield, whereas those of *H. pygmaea* are much longer, narrower and located closer to the margins of the shield.

Compressed and distorted specimens of *H. (N.) pygmaea* (Salter), *Eurypterus cephalaspis* Salter and *Parahughmilleria salteri* Kjellevig-Waering are easily misidentified, although each is a distinct species easily recognizable with suitable material.

In comparison to the associated *Hughmilleria banksii* (Salter) the differences are numerous and readily apparent. However the protruded anterior rim of the latter is a feature worth noting when using carapaces for specific determination.

Genus PARAHUGHMILLERIA Kjellesvig-Waering, n. gen.

Type species: *Parahughmilleria salteri* Kjellesvig-Waering.

Hughmilleridae of small size; dorsal shield semicircular; lateral eyes small, reniform, intramarginal, forward; metastoma with deep triangular notch anteriorly; female operculum short, expanded anteriorly and with narrow, protruding, lateral lobes; telson wide, wedge-like.

Distribution and stratigraphic range.—Upper Silurian (Downtonian), England; Lower Devonian, Germany; Upper Silurian, West Virginia; Middle and Upper Silurian New York, Pennsylvania.

Remarks.—*Parahughmilleria* differs from *Hughmilleria* mainly in the development of supplementary lobes on the operculum, a feature hitherto unknown in Silurian and Devonian forms, and previously known only in the upper Paleozoic genus *Adelophthalmus*. Størmer (1934a, p. 75) showed that "*Anthraconectes*" (*recte Adelophthalmus*) exhibited *Hughmillerian* characteristics, and Kjellesvig-Waering (1948, p. 5) considered "*Lepidoderma*" (*recte Adelophthalmus*) to have developed directly from *Hughmilleria*. Přibyl (1953, p. 7) in his discussion of the genus *Adelophthalmus*, agreed with this interpretation. The discovery of supplementary lobes in a form which had been included in the genus *Hughmilleria* is therefore of particular phylogenetic importance

Upper Ludlow at Batchcote Common, Shropshire, England and registered as No. In 48421 and counterpart No. In 43777 in the British Museum (Natural History).

24. *Erettopterus* (*Erettopterus*) *brodiei* Kjellesvig-Waering, n. sp., ×1.5, the holotype. A ramus, possibly the free one, of the chelicera. From the Downtonian at Ludford Lane, Ludlow, Shropshire, England and registered as No. 89411 in the Geological Survey and Museum, London.
25. *Erettopterus* (*Erettopterus*) *spatulatus* Kjellesvig-Waering, n. sp., ×0.5, holotype. Metasomal tergites and telson. This specimen is illustrated on Pl. 94, fig. 4, and Pl. 96, fig. 4, and was previously figured by Salter 1859, pl. 12, fig. 23, and Woodward, 1866–78 (1872) Pl. 16, fig. 4. From the Downtonian at the railway cutting, Ludlow, Shropshire, England. The holotype consists of two parts, No. 89397 which is registered in the Geological Survey and Museum, and its counterpart, No. In 44563, in the British Museum (Natural History).
26. *Stylonurus megalops* (Salter), ×1. A reconstruction of the carapace, based on the lectotype and specimen 89406; both are in the collections of the Geological Survey and Museum, London. From the Downtonian at the railway cutting, Ludlow, Shropshire, England.
27. *Hughmilleria* (*Nanahughmilleria*) *pygmaea* (Salter), ×4. The nearly complete chelicera. From the Temeside shale at the railway cutting, Ludlow, Shropshire, England. Registered as No. In 44560 in the British Museum (Natural History).
28. *Parahughmilleria salteri* Kjellesvig-Waering, n. sp., ×4. The metastoma. From the Downtonian at the railway cutting, Ludlow, Shropshire, England and registered as No. 89389 in the Geological Survey and Museum, London.
29. *Pterygotus* (*Pterygotus*) *grandidentatus* Kjellesvig-Waering, n. sp., ×1, the holotype. The distal end of the free ramus. From the Wenlock beds at Dudley, Worcestershire, England and registered as I. 3163 in the British Museum (Natural History).
30. *Pterygotus* (*Pterygotus*) *denticulatus* Kjellesvig-Waering, n. sp., ×1, the holotype. The distal half of a ramus, possibly the fixed ramus. From the Upper Ludlow at Whitcliffe, Shropshire, England and registered as No. In 48393 in the British Museum (Natural History).
31. *Pterygotus* (*Pterygotus*) *lightbodyi* Kjellesvig-Waering, n. sp., ×1, paratype. The distal half of the free ramus. From the Upper Ludlow at Whitcliffe, Shropshire, England and registered as No. In 48392 in the British Museum (Natural History).
32. *Pterygotus* (*Pterygotus*) *lightbodyi* Kjellsvig-Waering, n. sp., ×1, holotype. The nearly complete chelicera. From the Upper Ludlow at Whitcliffe, Shropshire, England and registered as No. 89436 in the Geological Survey and Museum, London.

in tracing the development of *Adelophthalmus* from *Hughmilleria* and through forms such as *Parahughmilleria*. It is also interesting to note, as another possibility, the migration of the lateral eyes from a marginal position in typical *Hughmilleria* such as *H. socialis* Sarle and *H. banksii* (Salter) to an intramarginal position in forms such as *H.* (*Nanahughmilleria*) *norvegica* (Kiaer) and *H.* (*Nanahughmilleria*) *pygmaea* (Salter), and still farther centrally in *Parahughmilleria salteri* and finally to the more central position in *Adelophthalmus*. The shape of the eyes also changes in the above genera from ovoid to reniform.

Parahughmilleria, aside from the Downtonian localities of England listed below, has been identified by Størmer (1936, p. 53) from the Lower Devonian of the Rhine region. *Hughmilleria bellistriata* Kjellesvig-Waering from the Upper Silurian (Wills Creek Shale) of Hardy County, West Virginia, apparently should be referred to the genus *Parahughmilleria*. *Hughmilleria phelpsae* Ruedemann from the Silurian, lower Vernon Shale, of New York also should be referred to this genus. The problematical *Eurypterus maria* Clarke from the Shawangunk grit of New York and Pennsylvania should be included in this genus. All exhibit the characteristic semicircular carapace and forward position of the eyes.

PARAHUGHMILLERIA SALTERI Kjellesvig-Waering, n. sp.
Pl. 95, figs. 1–5; text-fig. 1, figs. 6–12; text-fig. 2, fig. 28

Eurypterus pygmaeus SALTER, 1859, vol. XV, p. 232, pl. X, figs. 5,6,7,8; WOODWARD, 1872, pl. XXVIII, figs. 6–7.
Eurypterus cf. *pygmaeus* SCHLÜTER, 1881, p. 210, 211.
Hughmilleria (?) *pygmaea* STØRMER, 1936, p. 53–54, pl. 1, fig. 3, pl. 7, fig. 4.

This species is very distinct, but previously was erroneously included under *Hughmilleria* (*Nanahughmilleria*) *pygmaea*(Salter). Documentary proof is lacking that this form might not have been the species that Salter meant to describe as *H.* (*N.*) *pygmaea* rather than the small *Hughmilleria* restricted in this paper to *H.* (*N.*) *pygmaea*, as it is the more common of the two forms. However, the specimen figured first by Salter is considered *H.* (*N.*) *pygmaea*, whereas the other species is herein described as a new form, named in honor of J. W. Salter. Both species are very distinct; the differences between the two are numerous and are discussed under *H.* (*N.*) *pygmaea*. The confusion concerning both species likewise has been outlined under the description of *H.* (*N.*) *pygmaea*.

Parahughmilleria salteri is based on a holotype and four paratypes that show the essential and characteristic features of this easily recognizable form.

The prosoma (Text-fig. 1, figs. 6–9) is widely rounded, nearly semicircular, with the base forming a straight line. It is highly arched, much more so than most other eurypterids, and is surrounded by a narrow, marginal rim. Specimen No. 89420, which is preserved in sandstone and retains original convexity, has a dorsal shield which measures 8.8 mm. in length and 12.4 mm. in width. The height, however, is 3.5 mm. The sides adjoining the margin of the prosoma are unusually steep (Text-fig. 1, figs. 8 and 9).

Measurements of the dorsal shield are as shown in the following table.

Uncrushed dorsal shields, mainly those preserved in sandstone, have an average length to width ratio of 6.8:10. Crushed shields are relatively wider.

The lateral eyes are small, reniform and placed intramarginally and anteriorly on the prosoma. In specimen No. 89420 they measure 2.0 mm. in length, 1.2 mm. in width and are located on the prosoma, 2 mm. from the anterior margin, 4.7 mm. from the posterior margin and 1.5 mm. from the lateral margins (see Text-fig. 1, fig. 5). Another specimen (No. In 44562) has lateral eyes which measure 2.7 mm. in length and 1.7 mm. in width and are located on the prosoma, 2.2 mm. from the anterior margin, 4.5 mm. from the posterior margin, and 1.7 mm. from the lateral margins.

The ocelli are small, placed almost centrally on the prosoma at a line connecting the posterior end of the lateral eyes and do not occur on a mound as in many other eurypterids.

No ornamentation is present on the prosoma. Transverse lines are sometimes noted (Salter, 1859, p. 10, fig. 7) on the anterior of the prosoma. These lines, however, are due to compression and are not actual structures

Specimen number:	Preserved in:	Condition	Length in mm.	Width in mm.	Ratio L to W
89486	shale	uncrushed	3.2	4.6	6.9:10
89387	sandy shale	crushed	6.6	10.0	6.6:10
In 44561	shale	crushed	8.0	13.5	5.9:10
In 44559	shale	mainly uncrushed, incomplete	8.5	12.4 (est.)	6.9:10
89394	shale	crushed, incomplete	8.7	13.8 (est.)	6.3:10
89420	sandstone	uncrushed	8.8	12.4	7.1:10
89381	shale	crushed	8.8	13.7	6.4:10
In 44562	sandy shale	slightly crushed	9.0	14.0	6.4:10
89395	shale	crushed	9.2	13.6	6:8.10
In 44573	sandstone	uncrushed	9.6	15.0	6.4:10
I.1403	sandstone	uncrushed, incomplete	9.7	14.0 (est.)	6.9:10
In 43776	sandstone	uncrushed	10.5	16.0	6.6:10

of ornamentation. Well preserved specimens in shale, retaining all details, show the prosoma to be smooth.

The underside of the prosoma is practically unknown. Specimen No. 89387, a counterpart, retains the third appendage or second walking leg of the left side and the fifth appendage or fourth walking leg of the right side. Both are devoid of any spines and appear terete and end in a single pointed spine. The rest of the prosomal legs are unknown. The metastoma is preserved in specimen No. 89389. It is quite elongated, truncate at the posterior end and deeply notched with an inverted, wide, triangular area at the anterior end (see Text-fig. 2, fig. 28).

The mesosoma is known mainly from the dorsal side. Specimen No. 89387 (see Text-fig. 1, fig. 12) retains the mesosoma in its entirety. The first tergite is considerably reduced and greatest width is attained at the middle of the third tergite.

The measurements of this specimen are as follows:

	Length	Width
Tergite 1	1.0 mm.	9.5 mm.
Tergite 2	1.3 mm.	10.1 mm.
Tergite 3	1.3 mm.	10.0 mm.
Tergite 4	1.3 mm.	9.3 mm.
Tergite 5	1.3 mm.	8.5 mm.
Tergite 6	1.3 mm.	8.0 mm.
Tergite 7	1.6 mm.	6.8 mm.
Tergite 8	1.8 mm.	5.5 mm.

The metasoma is known also in its entirety. The above measured specimen reveals no appreciable contraction occurring between the seventh and eighth tergites of the opisthosoma as in many other genera. Another specimen (No. 89386) figured by Salter (1859, pl. X, fig. 6) and shown here in Plate 2, figure 4, and Text-fig. 1, fig. 10, retains the posterior part of the metasoma.

The measurements of this specimen are as follows:

	Length	Width (at posterior)
Tergite 9	2.3 mm.	6.1 mm.
Tergite 10	2.7 mm.	5.4 mm.
Tergite 11	3.0 mm.	4.4 mm.
Tergite 12	3.5 mm.	3.2 mm.
Telson	7.3 mm.	3.0 mm. at base

The telson is flat, wedge-shaped, and broad at the anterior. A narrow slit is noted at the end which undoubtedly represents a slight carina. Salter (1859) reports a carina on the dorsal side.

Only one operculum has been found and this has proved to be very interesting in revealing the development of lateral lobes which hitherto were unknown except in species of the late Palezoic genus *Adelophthalmus*. Specimen 89391 retains a complete operculum with female median appendage. This specimen has been designated as the holotype of the species (Text-fig. 1, fig. 11 and Pl. 2, fig. 5). It is excellently preserved

in olive shale and comprises two long opercular flaps, rounded at the corners and separated from each other at midsection and above the median appendage. The latter is short, club-shaped, and consists of two segments. The anterior part is wide and rounded and converges posteriorly. The distal segment is not complete but enough is preserved to show that it is short and narrow. On the sides of the median appendage, but definitely part of the opercular flaps, are two long lobes which extend past the base of the operculum. These lobes appear to be free of the median appendage and the opercular flaps and seem to be attached to the flaps only at the anterior end of the lobe. No suture was noted at the point of attachment.

The median appendage is devoid of any ornamentation but the opercular flaps reveal small, semilunar or crescentic scales, and long, diagonal linear markings.

The ornamentation of the opisthosoma, except for that noted on the operculum, comprises long, parallel, linear striae, commonly three lines, transversely along the anterior of the tergites. The rest of the tergite, as well as the telson is smooth.

Horizon and locality.—All specimens reported here are from the Downtonian. The holotype (No. 89391) is from the Ludlow railway cutting at Ludlow, Shropshire, England, collector unknown. Paratypes (Nos. 89386 and 89387) are also from the same location, collected by Robert Lightbody 1858–59, and paratype In 43776 is from the Downton sandstone, Bradnor Hill, Kington, Herefordshire, collected by R. Banks, about 1850; No. 89420 is from the Downtonian at Ludford Lane, Ludlow, Shropshire. Specimens No. 89381, 89389, In 44559, In 44561 and In 44562 are from the railway cutting, Ludlow, collected by R. Lightbody 1858–59. Specimens No. 89394 and 89395 are from the same locality, collector unknown. Specimen In 44573 is from the base of the Downton sandstone, Ludford Lane, Herefordshire, collected by R. Lightbody about 1858. Specimen I. 1403 is from the Downton sandstone at Kington, Herefordshire, collected by J. E. Lee, Oct. 1885. Specimen No. 89486 (preserved in olive shale) was cited because it is the smallest individual, although locality and collector are unknown. Two specimens, PE 4979 and PE 4980, consisting of a prosoma and a tergite respectively, were collected from the Temeside shale at Tin Mill Race near Downton Castle, Herefords. The latter were collected by Robert H. Denison and are in the collection of the Chicago Natural History Museum.

Salter's figured specimens (1859) are also from the Downtonian beds. The specimen figured in pl. 10, fig. 5, comes from the Ludlow railway cutting, Ludlow, whereas the specimen on pl. 10, fig. 7, is from Ludford Lane, Herefordshire. Both collected by R. Lightbody.

Repository.—Holotype (No. 89391), Paratypes (89386, 89387, and 89420) and specimens No. 89381, 89386, 89389, 89394 and 89395 are in the collection of the Geological Survey and Museum (London). Paratype No. In 43776 and specimens No. In 44559, In 44561, In 44562, In 44573 and I. 1403 are in the British Museum (Natural History).

Salter's specimens (1859, pl. 10, fig. 5 and fig. 7) are Nos. In 49397 and In 43795 respectively and are in the collection of the British Museum (Natural History).

Remarks.—*Parahughmilleria salteri* differs considerably from *Hughmilleria* (*Nanahughmilleria*) *pygmaea* (Salter) and these differences have been listed in the discussion of the latter.

Størmer (1936, p. 53, pl. 1, fig. 3; pl. 7, fig. 4) lists this species from the Lower Devonian of Germany. The German form, however, has short, pointed epimera on the metasoma, which so far are unknown in the British specimens studied by this writer. The latter may be a subspecies of *P. salteri*.

Parahughmilleria bellistriata (Kjellesvig-Waering) from the Upper Silurian Wills Creek shale of Bass, Hardy County, West Virginia, is much like *P. salteri*. The West Virginian form has a slightly longer prosoma which is well ornamentated with striae on the anterior part. The latter feature is in contrast to the smooth prosoma of *P. salteri*.

Genus SLIMONIA Page, 1856

SLIMONIA (?) STYLOPS (Salter)

Pterygotus stylops SALTER, 1859, p. 55, pl. 12, fig. 47; BIGSBY, 1859, p. 322; WOODWARD, 1877, p. 68; ETHERIDGE, 1888, p. 67; DIENER, 1924, p. 13; KING, 1934, p. 563.

Pterygotus (?) stylops WOODWARD 1872 (1866–

1878), p. 91, fig. 24; O'CONNELL, 1916, p. 46; STØRMER, 1934, p. 95.

This highly problematical species still remains as enigmatic as when it was first described. Only one specimen is known and this comprises the anterior part of a carapace with compound eyes placed at the antelateral margins. In some respects it resembles *Slimonia* but nothing definite can be determined.

In the Downtonian, two telsons have been described which might belong to the carapace in question. These are the peculiar *Salteropterus abbreviatus* (Salter) and *Hughmilleria* (*Hughmilleria*)(*?*) *acuminata* (Salter). Both are equally as rare as *S.* (*?*) *stylops*. It would not be surprising to find that the latter is part of one of the two species mentioned above. In particular, the writer suspects it is quite possible that *S.* (*?*) *stylops* is the carapace of *Salteropterus abbreviatus*, as both reveal affinities with *Slimonia*. Another possibility is that it could represent a *Mixopterus*, evidence of which has been reported in these beds (Kjellesvig-Waering, 1951, p. 21). At least it can be stated with certainty, however, that the form does not represent the Pterygotidae.

Horizon and locality.—Downtonian at Kington, Herefordshire, England. The type was not available for this review.

Genus SALTEROPTERUS Kjellesvig-Waering, 1951

SALTEROPTERUS ABBREVIATUS (Salter)

Eurypterus abbreviatus SALTER, 1859, p. 234, pl. 10, fig. 18; BIGSBY, 1859, p. 321; WOODWARD, 1864, p. 107; ——, 1872, (1886–1878), p. 148, pl. 28, fig. 14; ——, 1871, p. 261; ——, 1877, p. 64; ETHERIDGE, 1888, p. 52; O'CONNELL, 1916, p. 38; DIENER, 1924, p. 15; KING, 1934, p. 563.

Salteropterus abbreviatus KJELLESVIG-WAERING 1951, p. 15–17, pl. 2, figs. 6,7; text-figs. 2D–H; STØRMER, 1955, p. 30, fig. 21; fig. 5a,b; KJELLESVIG-WAERING 1958, p. 301; ——, 1958a, p. 1140.

This is one of the rare species of the Downtonian and is still known from only three telsons and part of the metasoma. It is becoming increasingly suspicious that the carapace which Salter described as *Pterygotus stylops*, and which here is referred questionably to *Slimonia*, may eventually be found to be the other extremity of *Salteropterus*. Also, it is possible that the leg fragment described by Kjellesvig-Waering (1951, p. 22, pl. 3, figs. 3,4) as *Tarsopterus* (*?*) sp. may be referable to this unusual and unique eurypterid.

In the writer's description of the genus *Salteropterus* (1951, p. 15) he stated that there is a strong possibility that the "supplementary telson" was segmented along the stem. This all occurs posterior to the normal telson. However, at the time, he agreed that perhaps the segmentation consisted rather of cracks along the stem than actual segments, as segmentation of the eurypterid telson was then unknown. In a recent paper, the writer (1958, p. 299) found that in a well preserved specimen of *Carcinosoma newlini* (Claypole), distinct segmentation is actually present, and that this segmentation occurs, as in *Salteropterus abbreviatus*, on the part designated as the "supplementary telson," which normally is broken off, or aborted, during ecdysis. It therefore appears that the telson of *Salteropterus* also is segmented along the area posterior to the normal telson.

Horizon and locality.—Downtonian. Salter's specimen (1859, pl. 10, fig. 18) is from Kington, Herefordshire. Woodward's specimen (1871, p. 261) is from Perton, near Stoke Edith, Herefordshire, and the specimen reported by Kjellesvig-Waering is also from the latter locality.

Repository.—Both these specimens are in the collection of the Geological Survey and Museum, London, England where they are registered as No. 88911 (with counterpart, 5998) and Zf2864, respectively.

SALTEROPTERUS (*?*) LONGILABIUM Kjellesvig-Waering, n. sp. Pl. 96, fig. 2

Pterygotus punctatus SALTER, 1859, pl. XI, fig. 4. *Slimonia* (*?*) WOODWARD, 1866–78, p. 154, 155.

The identity of this well known metastoma (Pl. 96, fig. 2) remains almost as controversial as when it was first incorrectly referred by Salter to *Carcinosoma punctatum*. Woodward (1866–78, p. 154,155) recognized that the metastoma of *C. punctatum* could not possibly be of a long, narrow type, but was of the broad, shield-like type which he had previously noted on specimens of *Carcinosoma scorpioides* (Woodward) from the Lesmahago locality. He therefore correctly figured the true metastoma of *C.*

punctatum on text-fig. 50 and noted with regard to the long, narrow metastoma that it "must have belonged to some species of another genus—the form of the plate being nearer that of *Slimonia acuminata*." It is undoubtedly true that the metastoma is not of the Carcinosomatidae but represents an altogether different family.

The present writer agrees with Woodward that this metastoma is suggestive of a form nearer to *Slimonia* than any other genus. It is definitely not a *Slimonia*, however, as the metastoma in question does not retain the deep anterior notch, or cordated area, of *Slimonia*. The only genus which seems to indicate a form related to *Slimonia* within the Silurian of the Welsh Borderland is the genus *Salteropterus*. The metastoma is unknown as yet in that genus, but it is known that *Salteropterus* reached the proportions indicated by the large metastoma in question. In this connection, it is of particular interest to record a fragment of a tergite (No. 89597) from the same locality and horizon, which reveals identical ornamentation, in the form of raised, prominent mucrones, as that which was recorded for the genus *Salteropterus* (Kjellesvig-Waering, 1951, text-figs. 2D,H) in the Downtonian. This small fragment measures 20 mm. in length but probably represented a tergite of 40 mm. in length. The largest mucrone measures 1.2 mm. in width.

The metastoma described here has been named in order to give expression to this unusual eurypterid. The holotype is considered to be the metastoma described by Salter (1859, pl. XI, fig. 4) and Woodward (1866–78, p. 154,155) and which is figured here on Plate 96, figure 2. It is very narrow, tapering to the posterior and rounded at both ends without a notch at the anterior. The greatest width occurs anterior to the midsection.

Measurements of metastoma:

Length:	106.0 mm.
Greatest width:	36.0 mm.
Width at midsection:	31.0 mm.

Horizon and locality.—Middle Ludlow; Mocktree Shales: Leintwardine, Herefordshire, England. The holotype was collected by Alfred Marston, about 1855. Specimen No. 89579 is also from the same horizon and locality.

Repository.—The holotype (No. 39386) is in the collection of the British Museum (Natural History), whereas specimen No. 89579 is in the collection of the Geological Survey and Museum, London, England.

Family PTERYGOTIDAE Clarke & Ruedemann, 1912

Among the species of Pterygotidae, the form known as *Pterygotus problematicus* Agassiz, or *Pterygotus problematicus* Salter, is perhaps as well known as any, and includes one of the longest and most complex synonymies of any eurypterid. Few species of eurypterids are as well known in spite of the fact that no one can properly define the species. The species, described from insufficient and undiagnostic fragments, rapidly became known, and its range extended until the "species" (actually the family Pterygotidae) encompassed the entire Silurian and part of the Devonian. Although the name is intimately associated in eurypterid history as one of the more famous, it is, unfortunately, not possible to continue its use. The species *Pterygotus problematicus* Agassiz has actually no meaning and, more or less, is synonymous with the family Pterygotidae as it has been used indiscriminately by many authors for any indeterminable fragment retaining pterygotid ornamentation.

The confusion attending this species was started in 1839 by Murchison in his "Silurian System," part II, p. 606, who recorded a letter from Louis Agassiz. On page 606, Murchison writes: "The fishes have been named, and are briefly described by M. Agassiz from drawings sent to him by myself, but more detailed descriptions of them will hereafter appear in his great work, Récherches sur les Poissons Fossiles."

"The figures 1, 2, 3," says M. Agassiz, "are very probably fragments of the skin (shagreen) of some Placoid, of which the teeth and the vertebrae are found detached in the same beds. Examine the drawing of the *Squaloraia* which I sent to the Geological Society, and you will perceive that the skin consists of similar tubercles, though these appear to me more pointed. They perhaps belong to the same animal of which fig. 6 represents the tooth [note: fig. 6 of Plate 4

is of a gnathobase, probably the central part of the gnathobase of the coxa of the swimming leg of an *indeterminable* eurypterid. Labeled by Murchison, "Teeth of *Sphagodus pristodontus*"]. This tooth is sufficiently characterized to be distinguished from all those which have been already described. It constitutes a new generic type, which may be designated by the name *Sphagodus* (slaughtering or murderous tooth) and the species *Sphagodus pristodontus* Agass."

The label at the bottom of pl. 4 is as follows: "Portions of *Pterygotus problematicus* (Ag.) belong undoubtedly to the same animal as the Seraphim of the Old Red Sandstone. The more I know of this creature, the more I am tempted to believe that it was a fish; but how absolutely decide upon it, when we have neither discovered head nor tail, but only large wings. It may provisionally bear the name of *Pterygotus problematicus*, Agass. (wing fish)."

The specimens listed as *Pterygotus problematicus* on pl. 4, figs. 4 and 5, (of "The Silurian System") are small patches of integument of a pterygotid; a more definite determination is not possible. The specimen listed as *Sphagodus pristodontus* is the central part of the gnathobase of a coxa of the swimming leg of an eurypterid. It is impossible to determine the form, or forms, that the two patches of integument represent, as all Pterygotidae have similar semilunar scales. Inasmuch as the two patches of integument came from the Upper Ludlow Bone Bed, they could belong to any of seven known, and perhaps more, Pterygotidae: *Pterygotus* (*P.*) *denticulatus*, *P.* (*P.*) *lightbodyi*, *P.* (*P.*) *ludensis*, *Erettopterus* (*T.*) *gigas gigas*, *E.* (*T.*) *gigas megalodon*, *E.* (*E.*) *spatulatus*, and *E.* (*E.*) sp., found in the Upper Ludlow or Lower Downtonian. Regarding the part identified as *Sphagodus pristodontus*, this is also undiagnostic. In this case, the writer would not venture to state what family the fragment represented. All that can be determined is that it is part of an eurypterid.

Pterygotus anglicus Agassiz, a form commonly given as the genotype of *Pterygotus*, was not described until 1844. This form, however, was properly described and illustrated and was based on a number of diagnostic parts. Regarding this form Agassiz, 1844, page XIX (translation from Huxley 1859, p. 5), wrote:

"The plate A accompanying this monograph, represents many well preserved fragments of one of those gigantic Crustacea of the Old Red, collected by Mr. Webster in the neighborhood of Balruddery, in Scotland. Deceived by the scaly aspect of a portion of the carapace, I at first believed that this might be the type of a peculiar genus of fishes, and to that class I referred *Pterygotus*, in my enumeration of the fossil fishes of the Silurian system, published in Murchison's great work. This genus, founded upon very imperfect fragments from the Ludlow rocks, is now well known, from the investigations which I have been able to make of a new species from the Old Red, discovered by Lyell, in Forfarshire, and of which Mr. Webster has found more characteristic remains at Balruddery."

There has never been any problem as to what constituted *Pterygotus anglicus* Agassiz, although considerable doubt has arisen as to what was the genotype of *Pterygotus*. Prantl & Přibyl, 1948, p. 75, give an excellent résumé of the problem. The confusion attending *Pterygotus problematicus* Agassiz, was further complicated by Salter (1852, p. 386, pl. 21, figs. 1–2) who described under this name the chelicera of a large form. It is here illustrated on Plate 96, figure 1. This form, however, is from the Upper Ludlow and represents a subspecies of *Erettopterus gigas* (Salter) (see *Erettopterus* (*E.*) *gigas megalodon*). Later Salter (1859, pl. XII) described several more parts which were attributed to *Pterygotus problematicus* Agassiz. Of these, figs. 7 and 9 have been redescribed as *Pterygotus* (*Pterygotus*) *lightbodyi* Kjellesvig-Waering, n. sp.; fig. 8 is a chelicera which is referred to *Pterygotus* (*Pterygotus*) *ludensis* Salter; fig. 9a is part of Salter's 1852 type which has been referred to *Erettopterus* (*T.*) *gigas megalodon* Kjellesvig-Waering, n. subsp., and figs. 10 to 17 and 20–21 are referred to indeterminable Pterygotidae as the specimens are undiagnostic. None can be referred to *Pterygotus problematicus* Agassiz because the species is indeterminable as it is based on parts (integument) that are undiagnostic even on the generic and subgeneric level.

The answer to the problem as to what con-

stitutes the genotype of *Pterygotus*, in this writer's opinion, is clear. The genotype is *Pterygotus anglicus* Agassiz 1844 because this form was properly described from diagnostic specimens. The name *Pterygotus problematicus* Agassiz, 1839, has no meaning inasmuch as the basis of the species represented undiagnostic parts which may repreent not only more than one species but more than one genus or subgenus. The name *Pterygotus problematicus* Agassiz should be discarded as *nomen vanum*, as it is meaningless.

The family Pterygotidae, at the present time, consists only of the genus *Pterygotus*, which is divided into three subgenera, namely, *P.* (*Pterygotus*), *P.* (*Acutiramus*), and *P.* (*Erettopterus*) (Størmer, 1955, p. 30–31). These subgenera are not of equal standing. *P.* (*Pterygotus*) and *P.* (*Acutiramus*) differ from each other mainly in the form of the chelicera. For example, *P.* (*Pterygotus*) has a chelicera which terminates in curved ends, whereas *P.* (*Acutiramus*) has acute terminations. The two subgenera have the same general type of telson which ends in a short spine or spur. The main basis for the separation of the subgenus *P.* (*Erettopterus*) from the other two subgenera, however, is not the chelicera, but the telson. The latter genus has a notch at the terminal end of the telson dividing this structure into a bilobed organ. The writer proposes that *Erettopterus* be considered a separate genus from *Pterygotus*. Indeed, the chelicera of *Erettopterus*, like the subgenera of *Pterygotus*, clearly reveals two distinct groups, which here are recognized as subgenera of the genus *Erettopterus*. Thus it is proposed that the family Pterygotidae be divided into two genera, *Pterygotus* Agassiz and *Erettopterus* Salter, each of which is based on the structure of the telson and is further divided into two subgenera respectively, which are all based on the structure of the chelicera. This results in a uniform classification in which each division is of eq ıal value.

It is therefore proposed that the following classification be adopted:

Family PTERYGOTIDAE Clarke & Ruedemann, 1912

Carapace with large, ovoid, marginal eyes; epistoma large, antelateral shields broad; chelicera large and very long with numerous large teeth; walking legs very slender, undifferentiated, cylindrical without spines, approximately equal in length; swimming paddle proportionately small; male appendage, club-shaped, female smaller; metastoma, ovoid, cordate or notched anteriorly; opisthosoma without constriction; telson expanded into paddle shaped organ; surface sculpturing consisting of large squamous ornamentation.

Distribution.—Australia, Europe and North America.

Stratigraphic Range.—Ordovician to Middle Devonian.

Genus PTERYGOTUS Agassiz, 1844

Genotype: *Pterygotus anglicus* Agassiz, 1844.

Pterygotidae of large size with an expanded telson which terminates in a spine.

Subgenus P. (PTERYGOTUS) Agassiz, 1844

Subgenotype: *Pterygotus anglicus* Agassiz.

Pterygoti with a subtrapezoid prosoma; chelicera with curved distal ends; teeth curved posteriorly, without serrations; metastoma ovoid, cordated anteriorly, very wide.

Subgenus P. (ACUTIRAMUS) Ruedemann, 1935

Subgenotype: *Pterygotus* (*Acutiramus*) *cummingsi* Grote & Pitt.

Pterygoti with a subquadrate prosoma; chelicera with acute distal ends; larger teeth anteriorly inclined, commonly serrated; metastoma cordated anteriorly, narrow, subelliptic in general aspect.

Genus ERETTOPTERUS Salter, 1859

Genotype: *Erettopterus bilobus* (Salter).

Pterygotidae of large size with an expanded telson which terminates in a deep notch, dividing the telson into a bilobed structure.

Subgenus E. (ERETTOPTERUS) Salter, 1889

Subgenotype: *E.* (*Erettopterus*) *bilobus* (Salter).

Erettopteri with a subquadrate prosoma, chelicera very long; each ramus is very nar-

row, with small curved teeth without serrations; metastoma cordated anteriorly deeply notched, very narrow.

Subgenus E. (TRUNCATIRAMUS)
Kjellesvig-Waering, n. subgen.

Subgenotype: *E.* (*Truncatiramus*) *osiliensis* (Schmidt).

Erettopteri with a hemielliptical prosoma; chelicera very short, tapering abruptly; teeth irregular, ranging from curved to straight to rhombic; principal tooth serrated; metastoma cordated anteriorly, subelliptical in general aspect.

Genus PTERYGOTUS Agassiz, 1844
PTERYGOTUS (PTERYGOTUS)
ARCUATUS Salter
Text-fig. 3, fig. 4

Pterygotus arcuatus SALTER, 1859, p. 95, pl. 11, figs. 10?,11?; pl. 13, figs. 8,12?,13?,15?,16?; BIGSBY, 1859, p. 322; WOODWARD, 1872 (1866–1878), p. 88–90, figs. 21?,22?,25?,26?; SALTER, 1873, p. 165; WOODWARD, 1877, p. 66; SCHMIDT, 1883, p. 66; ETHERIDGE 1888, p. 66; SEMPER, 1898, p. 80; SEEMANN, 1906, p. 54; O'CONNELL, 1916, p. 44; DIENER, 1924, p. 10; KING, 1934, p. 563; STØRMER, 1934, p. 95; ——, 1936, p. 39; PRANTL & PŘIBYL, 1948, p. 82.

The species was described from a syntypic series which was figured by Salter in his monograph, 1859, pl. 13, figs. 8,12,13,15 and 16. Of these, only figure 8, the free ramus of the chelicera, can be properly referred to this species and is herewith designated as the lectotype. Figs. 12 and 13 of the original description are tergites which might represent other pterygotids. Fig. 15 is the coxa of a walking leg which at present is not possible to correlate to this species. Figure 16 is an indeterminable fragment which may not represent part of an eurypterid.

Woodward (1866–1878) figured other parts of pterygotids which at present are not possible to determine as belonging to this species. These include his text-figs. 21 and 22, which are portions of the coxae of the walking legs and which may represent other pterygotids. His text-fig. 23 referred to *P. arcuatus* is a very peculiar metastoma which was not available for this review. It is referred, with considerable doubt, to *Erettopterus* (*Erettopterus*) *marstoni*. Text-figs. 25 and 26 are indeterminable fragments not available for this study and which may not represent eurypterids. The former had been figured by Salter, 1859, pl. XIII, fig. 16.

A large gnathobase of the coxa, nearly complete (89587), reveals 12 teeth (Text-fig. 3, fig. 40). The second to fourth tooth, inclusive, apparently are notched into double terminations. In width the gnathobase measures 52 mm.

Horizon and locality.—Middle Ludlow, Mocktree shales, Leintwardine, Herefordshire, England.

Repository.—Specimen No. 89587 is in the collection of the Geological Survey and Museum, London.

PTERYGOTUS (PTERYGOTUS) DENTICULATUS Kjellesvig-Waering, n. sp.
Text-fig. 2, fig. 30

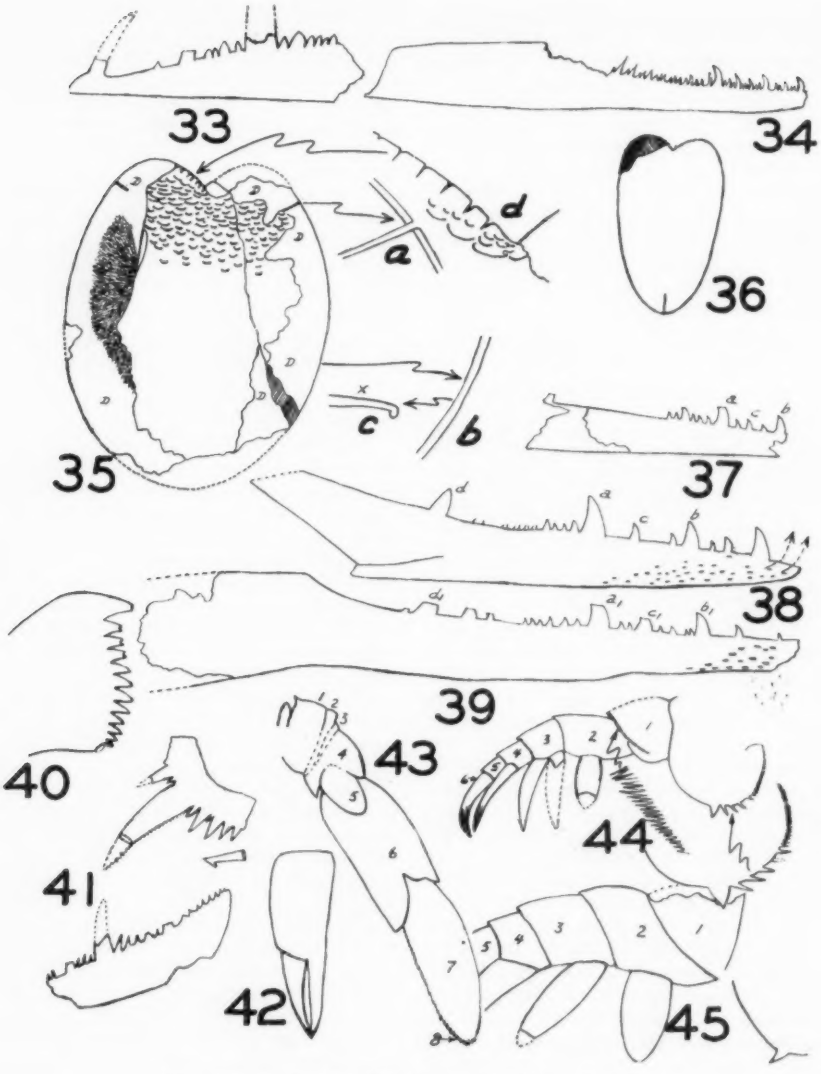
The holotype, and only specimen, of this distinct, easily recognizable form comprises slightly more than half of the anterior end of a ramus, presumably the fixed rami. It is a stout structure, the end of which is missing. The teeth are all unusually short, stout at the base, and peculiarly, sharply curved, posteriorly. The terminal tooth, in keeping with the likely characteristics of the other teeth, was also a short, stout structure. All teeth are very faintly ribbed.

The ramus measures 14.3 mm. in greatest thickness, whereas the prominent central tooth is 6.2 mm. in width and is estimated to be 12.5 mm. long.

Horizon and locality.—Upper Ludlow; preserved in greenish, calcareous shale and associated on the same bedding plane with articulate Brachiopoda and a fragment of a cephalopod, at Whitcliffe, Shropshire, England.

Repository.—Registered as No. In 48393 in the British Museum (Natural History).

Remarks.—This forms one of the Pterygotidae which undoubtedly has been mistakenly included in the false range of *Pterygotus problematicus* Agassiz. The present writer had considered this form as representing the fixed ramus of *P.* (*P.*) *lightbodyi*, the common species of the Upper Ludlow, until the fixed ramus of the latter was discovered in the collection of the Geological Survey and Museum (see holotype [No. 89436] of *P.* (*P.*) *lightbodyi*, Text-fig. 32).



TEXT-FIG. 3—Details of Silurian eurypterid morphology.

33. *Erettopterus* (*Truncatiramus*) *gigas gigas* (Salter), ×1. A poorly preserved fixed ramus. From the Downton sandstone at Kington, Herefordshire, England and registered as B.U. 14 in the Geological Museum, Birmingham University.

34. *Erettopterus* (*Erettopterus*) *spatulatus* Kjellesvig-Waering, n. sp., ×3. The fixed ramus of the chelicera. From the Temeside shale at Tin Mill Race, Downton Castle, Herefordshire, England and registered as PE 5124 at the Chicago Natural History Museum.

35. *Pterygotus* (*Pterygotus*) *lightbodyi* Kjellesvig-Waering, n. sp. ×0.5. An unusually well preserved

This rare form is easily distinguished from the associated *P.* (*P.*) *lightbodyi* by the small, thick, and curved nature of the teeth of the former. It differs from all other British Pterygotidae on the same basis. It is unfortunate that this easily recognizable form is apparently rare.

PTERYGOTUS (PTERYGOTUS) GRANDIDENTATUS Kjellesvig-Waering, n. sp.
Text-fig. 2, fig. 29

The holotype, and only known specimen, comprises the anterior half of the free ramus of a chelicera. This consists of a stout stem, with a very long terminal tooth. The latter rises vertically without any curving on the inside of the tooth until the tip is reached, where it is curved posteriorly. The base of this tooth is unusually thick. The other teeth on the ramus are curved and twisted into various directions (see Text-fig. 2, fig. 29a). The ramus measures 13 mm. in greatest thickness. The terminal tooth is 17.5 mm. long and 7.2 mm. wide at the base. All teeth are ribbed.

---

metastoma showing the sutures at the antelateral angles and the cushion of bristles present on the doublure. The outside surface (ventral face) of the metastoma is present only on the central part and is marked with squamous ornamentation at the anterior half. This face has been peeled away in the parts labeled as "D" which represent the doublure or dorsal plates of the metastoma. On the anterior left hand part of the doublure can be seen the inner edge of the doublure. Bristles, which occur crowded on the doublure, are exaggerated in size in order to indicate the direction of growth and extent.

35(a). Greatly enlarged to show the marginal rim and the junction of the two plates (suture).

35(b). The marginal rim of the doublure of the metastoma.

35(c). The junction of the outer (or ventral) surface of the metastoma and the doublure. The ventral surface is marked "X."

35(d). Blunt, thick, teeth-like projections on the anterior of the metastoma. Specimen is from the Upper Ludlow, Herefordshire, England and is registered as Nos. 89501–89502 in the Geological Survey and Museum, London.

36. *Erettopterus* (*Truncatiramus*) *gigas gigas* (Salter), ×0.5.Nearly complete metastoma showing a suture on the posterior end. From the Downtonian at the railway cutting, Ludlow, Shropshire, England and registered as No. 89359 in the Geological Survey and Museum, London.

37. *Erettopterus* (*Erettopterus*) *marstoni* Kjellsvig-Waring, n. sp., ×1. Part of the free ramus of the chelicera. From the Middle Ludlow, Mocktree shale, at Church Hill, Leintwardine, Herefordsire, England and registered as No. 39394 in the British Museum (Natural History).

38. *Erettopterus* (*Erettopterus*) *marstoni* Kjellesvig-Waring, n. sp., ×1, holotype. The free ramus. From the Middle Ludlow, Mocktree shale, at Church Hill, Leintwardine, Herefordshire, England and registered as No. In 43790 in the British Museum (Natural History).

39. *Erettopterus* (*Erettopterus*) *marstoni* Kjellesvig-Waering, n. sp., ×1, paratype. The fixed ramus. From the Middle Ludlow, Mocktree shale, at Church Hill, Leintwardine, Herefordshire, England and registered as No. In 43805 in the British Museum (Natural History).

40. *Pterygotus* (*Pterygotus*) *arcuatus* Salter, ×0.5. The gnathobase of the coxa of the swimming leg. From the Middle Ludlow, Mocktree shale at Leintwardine, Herefordshire, England.

41. *Erettopterus* (*Truncatiramus*) *gigas megalodon* Kjellesvig-Waering, n. ssp., ×0.5, holotype. The chelicera, which is also shown on Pl. 94, fig. 1. From the Upper Ludlow, Bed 10, a few hundred yards west of Hagley House, Lugwardine, Herefordshire, England and registered as No. 48045–48048 in the Sed wick Museum, Cambridge University.

42. *Carcinosoma punctatum* (Salter), ×1. The nearly complete chelicera. The ends of the rami have been reconstructed. From the Middle Ludlow, Mocktree shale at Leintwardine, Herefordshire, England and registered as No. 89581 in the Geological Survey and Museum, London.

43. *Carcinosoma punctatum* (Salter), ×1. The nearly complete swimming leg with joints 1 to 8 indicated. From the Middle Ludlow, Mocktree shale, at Leintwardine, Herefordshire, England, and registered as No. 89561 in the Geological Survey and Museum, London.

44. *Carcinosoma punctatum* (Salter), ×1. A well preserved and nearly complete first walking leg. The unique flat spine of the second joint with small pits on the edges is particularly well preserved in this specimen. The small spines of the first joint are also shown greatly enlarged. The round coxa is also highly characteristic and is enlarged to show details of the teeth along the gnathobase. From the Middle Ludlow, Mocktree shale, at Leintwardine, Herefordshire, England and registered as No. 89565 in the Geological Survey and Museum, London.

45. *Carcinosoma punctatum* (Salter), ×1. The first walking leg of a larger individual than shown on Text-fig. 44. The characteristic flat spine of the second joint is completely preserved and reveals the unusual blunt aspect of this structure. From the Middle Ludlow, Mocktree shale, at Leintwardine, Herefordshire, England and registered as No. 89583 in the Geological Survey and Museum, London.

Horizon and locality.—Occurs in highly calcareous, light green shale associated, on the same slab, with articulate Brachiopoda. From the Wenlock beds at Dudley, Worcestershire, England, collected by J. E. Gray, about 1860.

Repository.—The holotype is registered under No. I-3163 in the collections of the British Museum (Natural History).

Remarks.—For approximately one hundred years, eurypterids have been known from the Wenlock beds of the Welsh Borderland. Most of these are comprised of fragments of the integument of Pterygotidae which, almost invariably, have been referred to that "catch all" *Pterygotus problematicus* Agassiz, (Symonds *in* Woodward, 1872, p. 93). As stated in the introduction, no Pterygotidae can be identified to generic level, much less to species, by the presence of the scale-like ornamentation. It is still not safe to identify the scale-like markings of the patches of integument found in the Wenlock as *Pterygotus* (*Pterygotus*) *grandidentatus* as, commonly, Pterygotidae occur in groups of two or more species.

For comparison, *P.* (*P.*) *grandidentatus* differs from *P.* (*P.*) *lightbodyi* of the Upper Ludlow and *P.* (*P.*) *arcuatus* Salter of the Middle Ludlow in the development of the more vertical terminal tooth, which is not as curved as in the others and, more important, in the presence of highly disoriented teeth along the ramus.

It hardly seems necessary to compare this species to *Pterygotus* (*P.*) *lightbodyi* as the differences are readily apparent in the figures given.

PTERYGOTUS (PTERYGOTUS) LIGHTBODYI Kjellesvig-Waering, n. sp.
Text-fig. 2, figs. 23,31,32

Pterygotus problematicus SALTER 1859, pl. XII, figs. 7 and 9 (only).

This species, previously mistaken for *Pterygotus problematicus* Agassiz, is the most common element of the eurypterid fauna of the Upper Ludlow. It is a large species, very distinct, and with an unusual development of long teeth on the chelicerae.

The species is based on the holotype which comprises most of the chelicera, and two paratypes which include most of the free ramus of the chelicera. The arrangement of the teeth on the free ramus is very consistent and through this can be easily distinguished.

The chelicerae are armed with very long teeth, all vertically placed on each ramus and are nearly all gently curved backward. Some of the smaller teeth are irregularly placed. The central tooth of the free ramus (a) in the holotype is rounded at the end, by wear, but actually it must have projected well over the base of the opposing ramus. The terminal tooth is also unusually long, slender and gently curved.

The terminal part of the fixed ramus, however, definitely terminates in a multiple arrangement of teeth. This has been noted before (Kjellesvig-Waering, 1955, p. 1044) with regard to *Pterygotus* (*Pterygotus*) *waylandsmithi* of the middle Vernon (Silurian) shales of New York. In the British form the terminal projections are not well preserved, but it is thought (Text-fig. 2, fig. 32) that it comprises at least a double set of teeth which serve as a socket for the reception of the opposing, long, terminal tooth of the free rami, and also serving as a formidable grasping tool. The double tooth termination generally appears as a single tooth, inasmuch as the teeth are on separate planes and one generally is buried during deposition.

The rami of the chelicerae are very narrow in relation to the formidable teeth. They are both gently curved, with the fixed ramus being considerably more curved.

Several points useful in the identification of this species are apparent. Of these, the combination of the central tooth (a) and the short diagnonal tooth (f) is of particular diagnostic importance. Also, the end combination of the large terminal tooth and the rather large upright tooth (c) is of considerable importance in the identification of this species.

The measurements of the holotype are as follows:

Greatest thickness of fixed ramus:	8.0 mm.
Greatest thickness of free ramus:	9.0 mm.
Estimated length of central tooth (a):	26.0 mm.
Width at base of central tooth (a):	6.0 mm.

The measurements of the paratype No. In 48392 are as follows:

Greatest thickness of free ramus:	17.3 mm.

Estimated length of central tooth (a):	25.0 mm.
Width at base of central tooth (a):	7.0 mm.
Estimated length of terminal tooth:	25.0 mm.

The measurements of the paratype No. In 48421 and reverse, In 43777, are as folows:

Greatest thickness of free ramus:	13.4 mm.
Estimated length of central tooth (a):	20.0 mm.
Width at base of central tooth (a):	6.5 mm.

A remarkably well preserved metastoma, preserved in dark greenish gray shale, and associated with numerous articulate Brachiopoda, is referred to this species. It is illustrated on Text-figure 3, fig. 35 and reveals morphological data hitherto unknown. The specimen is preserved with the ventral side stripped off, in part, revealing the great doublure of the structure. This doublure was, of course, previously known by studies of Holm (1899, pl. 1, fig. 5; pl. 3, fig. 21) with regard to *Eurypterus remipes tetragonophthalmus* Fischer but, surprisingly, it was found that the doublure retained definite sutures at the antelateral angles (Text-fig. 3, fig. 35). Surrounding the metastoma is an inverted marginal rim much the same as the marginal rim which connects the dorsal shield, or carapace, with the ventral plates or doublure. The sutures of the doublure of the metastoma penetrate the marginal rim (Text-fig. 3, fig. 35a). These sutures, which may be named the antelateral sutures of the metastoma, are very distinct on the specimen but are partly covered over so that the entire suture cannot be determined (Text-fig. 3, fig. 35).

The doublure is covered with fine, short bristles, closely packed along the inner half of the doublure (Text-fig. 3, fig. 35). These bristles are directed toward the margin of the metastoma. It is these bristles that commonly are found in all Pterygotidae along the doublures and which have led to the erroneous determination of a "pore system" by Clarke & Reudemann (1912, pl. 80). The bristles, or hairs, were mistaken for pores: their function, as in other arthropods, is to form a cushion between any two surfaces that articulate in areas where one surface is covered by an adjacent articulating surface.

Along the anterior, emarginate area of the metastoma are developed several flat, teeth-like projections (Text-fig. 3, fig. 35a) which, indeed, probably functioned as part of the exterior of the mouth as commonly seen in the development of pointed teeth on the metastoma of other Eurypterida, particularly *Eurypterus*.

Evidence of a median suture on the external part of the ventral side of the metastoma is presented with regard to *Erettopterus* (*T.*) *gigas* (Salter) (p. 75, text-fig. 36). This has been known with regard to *Eurypterus pittsfordensis* Sarle (Kjellesvig-Waering, 1958, pl. 145, fig. 4) but only with respect to the anterior of the metastoma.

The metastoma recorded above measures 99 mm. in length through midsection, 108 mm. in greatest length and 87.5 mm. in greatest width. The specimen is registered as No. 89501 and 89502 in the collection of the Geological Survey and Museum, London, England. It is labeled as coming from the Upper Ludlow in Herefordshire, England. Unfortunately, no other data are given.

The discovery of sutures in the metastoma of eurypterids strongly suggests the fusion and modification of some appendages. Størmer (1944, p. 47) and Raw (1957, p. 188) consider the metastoma to be the anchylosed appendages of the seventh (pregenital) somite, a conclusion which seems to be greatly strengthened by the discovery of these sutured metastomae.

Horizon and locality—The holotype (89436) is preserved in fine grained sandstone and is associated with numerous articulate Brachiopoda on the same bedding plane. It is from the Upper Ludlow at Whitcliffe, Shropshire. Paratype In 48392 (Text-fig. 2, fig. 31) is preserved in sandy, green shale and likewise is associated on the same bedding plane with articulate Brachiopoda. This specimen also is from the Upper Ludlow at Whitcliffe and was collected by R. Lightbody, about 1858. Another specimen, (Text-fig. 2, fig. 23), No. In 48421 and counterpart, In 43777, is preserved in fine grained, gray colored, dolomitic shale and occurs on the same bedding plane as numerous articulate Brachiopoda and fragments of bryozoa. It was collected from high in the Upper Ludlow at Batchcote Common, Shropshire, by J. Harley.

Salter's (1859, pl. XII, figs. 7 and 9) two specimens, both free chelae, are from the Upper Ludlow at Whitcliffe and at Ludlow, Shropshire, England. The rest of the speci-

mens listed on that plate for "*P. problematicus*" belong to other Pterygotidae and not to *P.* (*P.*) *lightbodyi*. All specimens known of this species are restricted to the Upper Ludlow.

Repository.—Holotype is registered as 89436 in the collection of the Geological Survey and Museum, London whereas the two paratypes are registered as No. In 48392 and In 48421 with reverse In 43777, in the collection of the British Museum (Natural History).

Remarks.—The species has been named after Robert Lightbody, one of the group known as the "Ludlow Geologists" who made unusually valuable collections in the lower Paleozoic of the Welsh Borderland over 100 years ago. The collections amassed by Robert Lightbody, Richard Banks, A. Marston, P. B. Brodie, and others during this period deserve special commendation, as through them a good portion of the more famous and basic fossils of the lower Paleozoic of "Siluria" became known. It is therefore, with pleasure, that the writer names this form, which is the most important species in the eurypterid assemblage of the Upper Ludlow, after one of the more articulate collectors of eurypterids of this period.

This species is, undoubtedly, what erroneously had been considered in the literature as part of *Pterygotus problematicus*, although the latter included practically any part of the Pterygotidae that could be conveniently identified as a "*Pterygotus*." As explained under the discussion of *Erettopterus gigas* Salter, *Pterygotus problematicus* Agassiz is a name totally without standing, and should not be employed.

In comparison to other *Pterygotus*, obvious affinities are apparent with the upper Silurian, Bohemian, *Pterygotus* (*Pterygotus*) *barrandei* Semper (Prantl & Přibyl, 1948, p. 80) and the upper Silurian North American forms, *P.* (*P.*) *cobbi* Hall (Clarke & Ruedemann 1912, p. 371) from New York and *P.* (*P.*) *floridanus* Kjellesvig-Waering (1950, p. 229). These species have much in common regarding the structures of the chelicerae, and it may be that all should be included as subspecies of *Pterygotus cobbi*. Indeed Prantl & Přibyl consider the Bohemian *P.* (*P.*) *barrandei* as a subspecies of *P.* (*P.*) *cobbi*. Clarke & Ruedemann (1912) first pointed out the similarity between *P.* (*P.*) *cobbi* and *P.* (*P.*) *barrandei*. It might be best to continue separating each into species until more is known of each. At the present time each is known from hardly more than a single structure, the chelicerae, and in the case of the North American *P.* (*P.*) *cobbi*, by only parts of that structure. Nevertheless, the great similarity of the *P.* (*P.*) *cobbi-flo-i-danus-lightbodyi-barrandei* group remains and this may be of considerable correlative importance.

In comparison with each of the aforementioned species, the British *P.* (*P.*) *lightbodyi* differs in the much longer development of teeth on the chelicerae and in numerous details of these teeth much more readily apparent on direct comparison of the figures. In particular, the combination of the central tooth (a) and the diagonal tooth (f) is highly diagnostic.

From the overlying Downtonian *Pterygotus* (*Pterygotus*) *ludensis* Salter, it differs greatly, namely, in the much longer rami of the chelicerae and in the larger and different arrangement of the teeth. From the underlying Lower Ludlovian *Pterygotus* (*Pterytotus*) *arcuatus* Salter, the differences are not as great but nevertheless significant. Again the differences are mainly in the much greater development of the central and terminal teeth as well as the others.

Pterygotus (*Pterygotus*) *lightbodyi* is intimately associated with definite marine fossils in all three specimens which the writer has studied. In this respect it also resembles the ecological conditions in which the Bohemian *P.* (*P.*) *barrandei* is found. Until definite fresh water sediments are found associated with this species, the writer sees no good reason to consider its habitat other than marine, possibly shallow water and near shore.

It would be interesting to speculate that inasmuch as *P. barrandei*, *P. cobbi* and *P. floridanus* each occur associated with a large *Pterygotus* (*Acutiramus*), the same association will be found in the Welsh Borderland. To date, however, no *P.* (*Acutiramus*) has been found in the eurypterid faunas of England or Scotland. It is expected that this subgenus will be found to occur in the Ludlow assemblage.

PTERYGOTUS (PTERYGOTUS)
LUDENSIS Salter

Pterygotus ludensis SALTER, 1859, p. 79, pl. 12, figs. 4?,5?,6?; pl. 14, figs. 1,2?,3?,4–10,11?,12, 15(?),16(?),17(?),18(?); BIGSBY, 1859, p. 322; WOODWARD, 1866–1878, p. 76–79, pl. XVI, figs. 7,9, text-figs. 15,16; SALTER, 1867, p. 140, 238; ——, 1873, p. 193; WOODWARD, 1877, p. 67; ETHERIDGE, 1888, p. 66; SEMPER, 1898, p. 75; ELLES & SLATER, 1906, p. 220; SEEMANN, 1906, p. 54; CLARKE & RUEDEMANN, 1912, p. 113; O'CONNELL, 1916, p. 45; DIENER, 1924, p. 12; KING, 1934, p. 563; STØRMER, 1934, p. 95; ——, 1934a, p. 16.

Pterygotus problematicus SALTER, 1859, pl. 12, fig. 8.

(?) *Pterygotus problematicus?* SALTER, 1859, pl. 14, fig. 14 (?).

Pterygotus gigas SALTER, 1859, pl. 9, fig. 13.

Pterygotus (*Pterygotus*) *ludensis* STØRMER, 1936, p. 41; PRANTL & PŘIBYL, 1948, p. 104.

Not *P.* (*P.*) *ludensis* Salter

Pterygotus ludensis SALTER, 1859, pl. 9, fig. 18; pl. 12, figs. 1–3 (= *Erettopterus* (*T.*) *gigas gigas* (Salter).

In the original description (Salter, 1859) of this species, several parts were erroneously referred to this definite species, whereas certain parts rightfully of this species were relegated to another form.

The metasoma and attached telson on Salter's (1859) pl. 14, fig. 1, is here considered the lectotype, as it reveals a form that belongs to the subgenus *Pterygotus* (*Pterygotus*), and is unlike any other pterygotid in the Downtonian beds. The chelicera illustrated on the same plate (fig. 10) is of particular diagnostic value since it reveals the considerable differences that set this species off from any other Downtonian or Ludlow form. In Salter's pl. 14, therefore, figs. 1 and 4 to 10 belong to *P.* (*P.*) *ludensis;* figs. 2, 3 and 11–12, are undiagnostic fragments which may represent other pterygotids. On Salter's pl. 9, fig. 18, a telson is illustrated from the ventral side which Salter doubtfully referred to *P.* (*P.*) *ludensis*. This specimen, however, is actually the telson of *Erettopterus* (*T.*) *gigas gigas*. In the first three figures of pl. 12 (figs. 1–3), Salter figured two chelicerae and a metastoma as *P.* (*P.*) *ludensis*. These specimens properly belong to *Erettopterus* (*T.*) *gigas gigas*. On the same plate, figs. 4–6 were referred to *P.* (*P.*) *ludensis* by Salter, although these comprise indeterminable fragments which can only doubtfully be referred to the latter species.

On pl. 9, fig. 13, Salter (1859) figures a fragment of a wide metastoma under the species *Pterygotus gigas* (*Erettopterus* (*T.*) *gigas gigas*) which properly belongs to *Pterygotus* (*P.*) *ludensis*, as that type of metastoma is characteristic of the subgenus *P.* (*Pterygotus*).

Horizon and locality.—All specimens so far known are from the Downtonian. Salter's (1859) pl. 14, figs. 1 (lectotype), 2 (?), 3 (?), and 4–10, are from the Downtonian at the Ludlow railway cutting, Ludlow, Shropshire, and were collected by Richard Banks, about 1855; figs. 11 and 12 of the same plate are from the Downtonian at Trimpley, North of Bewdley, collected by G. E. Roberts, about 1855. Salter's (1859) pl. 9, fig. 13, specimen is from the Downtonian at Kington, Herefordshire, collected by Richard Banks about 1855. The chelicera figured by Salter (1859, fig. 8) as "*Pterygotus problematicus*" is also from the Downtonian at Kington, Herefordshire, collected by Richard Banks.

Genus ERETTOPTERUS Salter, 1859
ERETTOPTERUS (ERETTOPTERUS)
BRODIEI Kjellesvig-Waering, n. sp.
Text-fig. 2, fig. 25

The holotype, and only known specimen, comprises a chela, uncrushed, so that the teeth are seen in their original condition, all rounded in cross-section. The stem of the ramus, possibly the free ramus, is slightly tapering, and terminates at the anterior end in a prominent, rather sharp projection which is deeply grooved or notched, in the form of a deep trough, for the reception of the opposing terminal tooth. The terminal tooth is by far the largest; it is hook-like and curved backward, and situated not on the same plane as the succeeding, but offset to the side. This indicates that another, perhaps similar, tooth occurs on the other side of the ramus. Thus, in closing the chelicera, the terminal tooth of the opposing ramus would fit between the two large terminal teeth and into the terminal trough of this ramus. The terminal tooth is followed by numerous teeth, which are all curved backward, and appear in the form of a series consisting of large teeth followed by about four smaller and irregular sized teeth. All

teeth are ribbed. The stem of the ramus is ornamented with prominent, raised, elliptical markings, rather knob-like in appearance.

The terminal tooth measures 8.5 mm. in length, whereas the stem of the ramus measures 8.0 mm. in width at its widest part.

Horizon and locality.—The holotype is from the Downtonian of Ludford Lane, Ludlow, Shropshire; collector unknown.

Repository.—The holotype is registered as No. 89411 in the collection of the Geological Survey and Museum, London.

Remarks.—The species has been named in honor of the Rev. P. B. Brodie, whose early collections of Eurypterida did much to advance our knowledge of these fossils in the Welsh Borderland. The name is well known to all workers in this field, and the use of the name for this new and peculiar pterygotid may compensate for the writer's having to relegate *Eurypterus brodiei* Woodward to the synonymy of *Eurypterus cephalaspis* Salter.

This new pterygotid is one of the most peculiar, and comparison with other forms is therefore superfluous. The peculiar termination of the ramus in a double-tooth socket is not known definitely in the genus *Erettopterus* but is known in *Pterygotus* (*Pterygotus*) as, for example, *Pterygotus* (*Pterygotus*) *waylandsmithi* Kjellesvig-Waering & Caster, from the Silurian Vernon shales of New York. The similarity ends there, as the two have little in common.

ERETTOPTERUS (ERETTOPTERUS) MARSTONI Kjellesvig-Waering, n. sp.

Text-fig. 2, fig. 28; Text-fig. 3, figs. 37,39

Pterygotus punctatus SALTER, 1859, pl. 11, figs. 1–3; pl. 13, fig. 7.

(?) *Pterygotus arcuatus* WOODWARD, 1872 (1866–78), text-fig. 23?

Salter (1859) erroneously included the chelicerae of a pterygotid with *Carcinosoma punctatum*, which was at the time considered a *Pterygotus*. Woodward (1866–78, p. 154), in his descriptions of the same species, correctly excluded the chelate appendages but did not describe or refer the appendages to any other species. The four parts of the chelicera represent a large *Erettopterus* (*Erettopterus*) which is among the most distinct and easily recognizable species of the Middle Ludlow and is here redescribed as a new species.

The species is based on incomplete specimens, which together represent almost the entire chelicera. The holotype is the free ramus, figured here on Text-figure 3, fig. 38, and is registered as No. In 43790 in the British Museum (Natural History). This specimen was previously figured by Salter (1859, pl. 11, fig. 2). The paratype comprises most of the fixed ramus; it is here figured on Text-fig. 3, fig. 39 and is registered as In 43805 in the British Museum (Natural History). This specimen has been previously figured by Salter (1859, p. 11, fig. 1). Another free ramus is figured on Text-figure 3, fig. 37 but is not used in the original description of the species. The latter is introduced for comparative purposes to show the regularity and diagnostic characteristic of the teeth in comparison to the holotype. This specimen is registered as No. 39394 in the British Museum (Natural History). Another specimen referable to this species consists of the end of the chelicera and was figured by Salter, 1859, pl. 11, fig. 3.

The overall aspect of each ramus of the chelicera is that of being very slender and tapering to the curved distal end. On the holotype, a free ramus, the teeth are all curved backward and all are characteristically short. A large tooth (a) is present on the midsection of the ramus. The end of the ramus is broken off, but this probably terminated in a double tooth, as has been suggested for *E.* (*E.*) *brodiei* of the Downtonian. Directly behind the terminal tooth, (or teeth), is a large tooth, although not as large as the central tooth. Equally distant from the central tooth but posteriorly located is a rather large, and apparently diagnostic, tooth (d) which is diagonally placed on the ramus. Midway between the central tooth and the anterior tooth is another tooth (b) which appears to be of diagnostic value. The same may be said of the tooth (c) in between.

The paratype comprises most of the fixed ramus. Of particular diagnostic value is the slight but noticeable narrowing of the ramus anterior to the central tooth. As expected, the teeth of the free ramus are opposed on the fixed ramus having nearly the same

arrangement of teeth. These opposing teeth are identified on Text-fig. 3, fig. 39 by a_1, b_1, c_1, d_1. Both the free and fixed rami reveal deep, rather elongated pits on the anterior ends which probably were the sites of bristles, or groups of bristles, as in many modern arthropods.

All teeth on the chelicerae are finely ribbed as reinforcement. The original coloration is partly preserved in specimen 39394, which consists of a dark brown stem having black teeth.

The species is named in honor of Alfred Marston, one of the more articulate of the group known as the "Ludlow Geologists" who was responsible, along with Richard Banks, P. B. Brodie, and Robert Lightbody, for many of the early collections of fossils, in particular eurypterids and fishes, of the Silurian of the Welsh Borderland. As may be noted from this paper, these old collection (mainly made about 1855–1859), still reveal numerous unknown or undescribed species and morphological structures.

The peculiar metastoma figured by Woodward, 1872 (1866–1878), Text-fig. 23, is referred to this species with considerable doubt. It more likely represents an undescribed genus; however the specimen was not available for this review.

Measurements of chelicera:

Holotype: free ramus:	
Length of ramus along outer edge:	76.3 mm.
Overall length:	92.6 mm.
Width of ramus at center of tooth (a):	8.2 mm.
Length of tooth (a):	7.7 mm.
Width of tooth (a) at base:	4.0 mm.
Paratype: fixed ramus:	
Width of ramus at center of tooth (a_1):	9.0 mm.
Specimen 39394: free ramus:	
Width of ramus at center of tooth (a):	4.7 mm.

Horizon and locality.—Middle Ludlow, Mocktree shale. This species is intimately associated with typical marine fossils such as bryozoans, starfishes, articulate brachiopods, *Lingula*, and trilobites. All three specimens are preserved on hard greenish gray, finely micaceous shale. Holotype is from the Middle Ludlow, Mocktree shale, at Church Hill, Leintwardine, Shropshire, collected by G. Cocking, about 1855. Paratype is from the same locality and horizon, collected by Col. Colvin, about 1855. Specimen 39394 is also from the same locality and horizon, collected by Alfred Marston, about 1855. Salter's pl. 11, fig. 3 is also from the same horizon and locality.

Repository.—All three specimens reported here are in the collections of the British Museum (Natural History).

ERETTOPTERUS (ERETTOPTERUS) SPATULATUS Kjellesvig-Waering, n. sp.

Pl. 94, figs. 4–7; pl. 96, figs. 3,4; text-fig. 2, fig. 25; text-fig. 3, fig. 34

Pterygotus banksii (*pars*) SALTER, 1959, pl. xii, figs. 23,30,36,37,38,40,45; WOODWARD, 1872 (1866–1878), pl. xvi, fig. 4.
Pterygotus sp. KJELLESVIG-WAERING, 1951, p. 5.

This pterygotid also has had a complicated synonymy as it was erroneously included under *Hughmilleria banksii* (Salter) until Kjellesvig-Waering (1951, p. 5) recently referred some of the described specimens to *Pterygotus*. In the present classification, these specimens should properly be included under the genus *Erettopterus*. The confusion attending this species previously will not be repeated here as it has been reviewed by the writer (1951, p. 5). The pterygotid involved was until now without a name but it is one of the most distinct and easily recognizable forms of the Downtonian of the Welsh Borderland. It has been named *Erettopterus* (*Erettopterus*) *spatulatus* because of its shovel-shaped telson. Forms with a shovel- or fan-shaped telson, that is, telsons that are wider than long, are rare, and previously known only by the American *Erettopterus* (*Erettopterus*) *grandis* (Pohlman) from the Silurian (Bertie) Williamsville waterlime of the Buffalo area, New York. In contrast to the latter, however, *E.* (*E.*) *spatulatus* is not uncommon in the Downtonian of the Welsh Borderland.

The metastoma is unknown, although there exists a possibility that previously it has been mistaken for that of *Hughmilleria banksii* (Salter). Kjellesvig-Waering (1951), text-fig. 1, J and I, ascribes two metastomata, differing in length to width proportions, to *H. banksii*. This was a variation similar to that found by Clarke & Ruedemann in their description of *Hughmilleria socialis* Sarle who (1912, pl. 62, fig. 4) show two forms of

metastomata. However, now, considerable doubt exists that these authors are correct. At present, evidence is lacking to determine whether the broader or the longer form belongs to *Erettopterus* (*E.*) *spatulatus* or to *Hughmilleria banksii*, as neither metastoma has been found attached to any diagnostic part. The same can be said about the two metastomata figured by Clarke & Ruedemann (1912, pl. 62, fig. 4) as to which type belongs to *H. socialis* and which belongs to an undescribed pterygotid.

The holotype is the old, well known specimen, retaining the metasoma and telson, that was responsible for a great deal of the confusion that existed with *Hughmilleria banksii*. This was the specimen figured by Salter, 1859, pl. xii, fig. 23, and by Woodward (1866–1878) 1872, pl. xvi, fig. 4, and which is refigured here on Text-fig. 2, fig. 25, and Plate 94, figure 4. This is specimen No. 89379 in the collection of the Geological Survey and Museum and the counterpart is (In 44563) in the British Museum (N.H.). Aside from this specimen, the species is described and known from a well preserved chelicera and two carapaces, and other fragments. Another fixed ramus of the chelicera, used in this description, was figured by Salter (1859, pl. xii, fig. 40). This specimen was made available for this study by Mr. R. Baker of the British Museum (Natural History), (No. In 43794), who kindly sent the writer an excellent rubber cast.

This is apparently a small species among the Pterygotidae, a family which commonly reached gigantic proportions. All parts found, representing less than fifteen individuals, indicate a species of about 20 cm. in length.

The two carapaces (In 43793 in the British Museum and PE 4978 in the Chicago Natural History Museum) represent young individuals, as attested by the large lateral eyes (see pl. 94, figs. 5,6; pl. 96, fig. 3), which are greatly protruding over the level of the carapace. The base is straight and the antelateral angles rounded where the great lateral and ovoid eyes are located. The ocellar mound is very prominent, protruding, round, and about 1.0 mm. in diameter in both specimens and is approximately in the center of the carapace. The ocelli are small, placed on the anterior of the posterior half of the ocellar mound. No ornamentation is discernible. The carapace is surrounded by a narrow marginal rim.

Measurements of these carapaces are as follows:

	Width at base:	Width behind eyes:	Length:
PE 4978	8.1 mm.	7.8 mm.	5.3 mm.
In 43794	11.5 mm.	10.7 mm.	7.4 mm.

Eyes are located on the carapace:

	From anterior margin:	From posterior margin:	From lateral margin:
PE 4978	0.8 mm.	2.0 mm.	0.0 mm.
In 43794	1.5 mm.	3.0 mm.	0.0 mm.

	Apart at front:	Apart at back:	Length of eyes:	Width of eyes:
PE 4978	3.8 mm.	5.6 mm.	2.9 mm.	1.5 mm.
In 43794	5.3 mm.	6.5 mm.	3.8 mm.	2.3 mm.

Ocellar mound is located on the carapace:

	From anterior margin:	From posterior margin:	From lateral margin:
PE 4978	2.6 mm.	2.3 mm.	3.5 mm.
In 43794	3.7 mm.	2.8 mm.	4.8 mm.

The chelicerae are the long slender types that characterize the subgenus *E.* (*Erettopterus*). Two fixed rami are known. The fixed ramus is long, slightly tapering with evenly curved small teeth, but irregular in size. Midway along the ramus is a slightly more prominent tooth. This tooth measures 1.8 mm., whereas the ramus at this point is 3.7 mm. wide (PE 5124). See Text-figure 3, fig. 34.

The holotype, as stated above, is the specimen figured by Salter 1859, pl. xii, fig. 23, as the telson of *Hughmilleria banksii* (Salter). This specimen (No. 89397 of the Geological Survey and Museum, and the reversal, In 44563, in the British Museum (N.H.)) reveals several of the posterior tergites and a fan-shaped telson with a deep notch in the center and fine pointed serrations at the posterior fringe. It is refigured in Plate 94, figure 4, Plate 96, figure 4, and in Text-figure 2, fig. 25. The telson is very wide, wider than long, and measures 30 mm.

in width. The holotype retains fine scale-like or semilunar scales as ornamentation.

It is interesting to note that part of the original coloration of this species is discernible. In specimen PE 5124, a chelicera of this species and a telson of *Eurypterus cephalaspis* occur alongside each other (see Pl. 94, fig. 7 and Pl. 95, fig. 10). They are preserved in soft olive green shale, undoubtedly nonporous and impermeable and where replacement of the original chitin could not occur. Thus the original coloration is preserved. The chela of *E.* (*E.*) *spatulatus* is of a light brown color, not unlike the brown color of the young of the modern *Limulus polyphemus*, with contrasting black teeth. The nearby telson of *Eurypterus cephalaspis* contrasts with the chela in being of a darker brown with the scales on the central carina, and the lateral fringes, black. It might be permissible to speculate that the overall color of *E.* (*E.*) *spatulatus* is light brown with darker brown scales and with black teeth on the chelicerae.

Horizon and locality.—This species is so far known only from the Downtonian except for one record from the Upper Ludlow of the Welsh Borderland, which the writer questions. The holotype, No. 89397 and counterpart In 44563, is from the railway cutting, Ludlow, Shropshire, England, and collected by Robert Lightbody, 1858–59. Specimen No. 89407 is also from the same locality collector unknown. Nos. PE 4978 and PE 5124 are from the Temeside (olive) shales at Tin Mill Race, Downton Castle, Herefordshire, collected by Robert H. Denison. No. In 43794 is from the Downton sandstone at Ludford Lane, Shropshire.

Specimen No. 89416, a telson, is from the Downton sandstone at Kington, Herefordshire, collected by Richard Banks. Salter's 1859, pl. xii, figs. 36, 37, 38 are from the same locality and collected also by Richard Banks. Salter's 1859, pl. xii, fig. 40 is from the Downtonian at Ludlow, Shropshire, collected by Robert Lightbody. Salter's pl. xii, fig. 45 is from the Upper Ludlow at Whitcliffe, Ludlow, Shropshire. Salter's pl. xii, fig. 46 has been referred to another species, *E.* (*E.*) sp. Another telson, No. 89416, is from the Downtonian at Ludford Lane, Ludlow, Shropshire.

It seems that the age of Salter's specimen (1859, pl. 12, fig. 45), said to be from the Upper Ludlow at Whitcliffe, might be questioned inasmuch as all other specimens of this species are known only from the Downtonian. At any rate, the Ludlow age occurrence should be verified by more specimens. The species *E.* (*E.*) *spatulatus* is therefore essentially, if not entirely, a Downtonian species.

Repository.—The holotype, 89397, and counterpart In 44563, are in the Geological Survey and Museum and the British Museum (N.H.), respectively. Specimen No. 89407 is in the Geological Survey and Museum; PE 4978 and PE 5124 are in the collection of the Chicago Natural History Museum; In 43794 is in the British Museum (N.H.). The other specimens cited above are located as to depository by Salter (1859, pl. xii).

ERETTOPTERUS (ERETTOPTERUS) sp.

Pterygotus problematicus SALTER, 1859, pl. 12, fig. 15, fig. 46; WOODWARD, 1872 (1866–1878), text-fig. 19.

The anterior half of a peculiar metastoma was figured by Salter and Woodward as the metastoma of *Pterygotus problematicus*. The present writer is uncertain to what species this metastoma should be referred but the deep notch at the anterior part indicates that it properly belongs to the subgenus *Erettopterus* (*Erettopterus*). It is much too large to be indicative of *E.* (*E.*) *spatulatus*, which occurs in the overlying Downtonian beds. It is more likely to be representative of an undescribed species of the subgenus.

A telson, very poorly preserved, was referred to *Pterygotus problematicus* by Salter (1859, pl. 12, fig. 46) and apparently also represents an undescribed form. More material is needed, particularly a part of the chelicerae, or at least a better preserved telson, before the species can adequately be distinguished from the *Erettopteri* in the Middle Ludlow, and the overlying Downtonian. Both the metastoma and telson may belong to the same species.

Horizon and locality.—Upper Ludlow, Batchcote Common, Shropshire (telson) and Upper Ludlow, Ludlow, Herefordshire (metastoma).

Repository.—Geological Survey and Museum, London, England (telson).

ERETTOPTERUS (TRUNCATIRAMUS) GIGAS GIGAS (Salter)

Text-fig. 2, fig. 22; Text-fig 3, figs. 33,36

Pterygotus gigas SALTER, 1859, p. 83, pl. 8, figs. 1,2,3(?),4(?),5(?),6,7,8,9(?); pl. 9, figs. 1–12, 14–18; pl. 12, figs. 1–3; BIGSBY, 1859, p. 322; WOODWARD, 1866–1878, p. 79–85, text-figs. 17, 18; MARSTON, 1870, p. 409; SALTER, 1873, p. 189; WOODWARD, 1877, p. 67; SCHMIDT, 1883, p. 29; ETHERIDGE, 1888, p. 66; SEMPER, 1898, p. 75; ELLES & SLATER, 1906, p. 220; SEEMANN, 1906, p. 56; O'CONNELL, 1916, p. 45; DIENER, 1924, p. 12; KING, 1934, p. 563; STØRMER, 1934, p. 95.

Pterygotus ludensis (*pars*) SALTER, 1859, pl. 9, fig. 18; pl. 12, figs. 1–3; pl. 14, figs. 15(?), 17(?),18(?).

Pterygotus (*Erettopterus?*) *gigas* STØRMER, 1936, p. 41.

Pterygotus (*Erettopterus*) *gigas* KJELLESVIG-WAERING, 1951, p. 17, pl. 3, fig. 2.

Not *Erettopterus* (*Truncatiramus*) *gigas gigas* (Salter)

Pterygotus gigas SALTER, 1859, pl. 9, fig. 13 = *Pterygotus ludensis* Salter.

The species was described by Salter (1859) from a syntypic series collected by Richard Banks (see above synonymy). Of these specimens, the large carapace figured on pl. 8, fig. 1, is herein designated as the lectotype, and is the first specimen described and figured by Salter. Along with this carapace, another important specimen is figured on plate 9, fig. 1, which comprises a carapace with an associated chela of the chelicera. Of the rest of the specimens figured on pl. 9 in the original description, fig. 3, 4, 5 and 9 represent undiagnostic parts which may belong to the other Pterygotidae, while pl. 9, fig. 12 definitely is not of this species but is the metastoma of *Pterygotus* (*Pterygotus*) *ludensis* Salter. The metastoma of *E.* (*T.*) *gigas gigas* was figured by Salter (1859), pl. 9, fig. 3), Woodward (1866–78, fig. 18) and Kjellesvig-Waering (1951, pl. 3, fig. 2). The metastoma which served as the original of Salter's and Woodward's figures was available for this study; this metastoma is specimen No. 89359. It measures 54.5 mm. in length at center and 35.0 mm. in greatest width. It reveals a suture, hitherto unknown, at the posterior central extremity (see Text-fig. 36). Previously a suture was known at midsection on the anterior part of the metastoma (Kjellesvig-Waering 1958, text-fig. 25) in *Eurypterus pittsfordensis* Sarle, but this is the first evidence of presumably the same suture in the Pterygotidae (see discussion of the sutures of the doublure of the metastoma in *P.* (*P.*) *lightbodyi*, p. 57–58, text-fig. 35).

The chelicera is figured here in Text-figures *22* and *33*, although both specimens are not very well preserved, and the diagnostic central tooth is mainly broken out. Figure *22*, which is by far better preserved represents the free ramus. This specimen was figured by Salter, 1859, pl. 12, fig. 2, as *Pterygotus ludensis*.

The fixed ramus with its great central tooth is figured here on Text-figure 3, fig. 33; the specimen is very poor, being preserved in a very coarse sandstone mixed with shale. The end of the fixed ramus is not very clear. Another specimen, No. 89466, referable to this species, is a large telson retaining the entire left half. It measures 120 mm. in greatest length and 94 mm. in reconstructed width.

Horizon and locality.—All specimens which have been documented by figures, or which the writer has identified, are from the Downtonian. These include the following: Salter's 1859, pl. 8, figs. 1,2,3(?),4(?),5(?),6,7,8,9(?), pl. 9, figs. 1–12,14–16, representing specimens collected by Richard Banks, are from the Downton sandstone at Kington, Herefordshire. Specimen No. In 44581 is from the Downtonian Temeside shale at the Ludlow railway cutting, Ludlow, Shropshire. Salter's 1859, pl. 9, fig. 17 (89466) is represented by a large telson which was collected by Robert Lightbody in 1858, from the Downtonian at Bradnor Hill, Kington, Herefordshire. Salter's (1859) pl. 9, fig. 18, is from the Downtonian at the railway cutting, Ludlow, Shropshire. Salter's (1959) pl. 12, figs. 1–3 are from the Downtonian at Ludlow, Shropshire. His fig. 2, refigured here as Text-figure 2, fig. 22, and his fig. 3, refigured by Woodward 1872, text-fig. 18, again refigured here as Text-figure 3, fig. 36, were collected by Alfred Marston, 1857, the labels of which state that both are from the railway cutting at Ludlow, Shropshire. The specimen figured on Text-figure 3, fig. 33 is from the Downton sandstone at Kington, Herefordshire. The latter is specimen B.U. No. 14; another specimen, part of a telson (B.U. 16) is also from the same horizon and locality. A part

of a telson (PE 4984) was collected by Robert H. Denison in the Downtonian, Temeside shales, preserved in olive shale, at Tin Mill race near Downton Castle, Herefordshire. It is also known from the lower Downtonian at Perton, Herefordshire (Kjellesvig-Waering, 1951, p. 17).

Repository.—The original of Text-figure 2, fig. 22 is registered as No. 89410 in the collections of the Geological Survey and Museum. The original of text-figure 3, fig. 33 is registered at B.U. 14 in the collections of the Geological Department of the University of Birmingham. B.U. 16 is also in the same collection. PE 4984 is in the collections of the Chicago Natural History Museum. The telson figured by Salter, 1859, pl. 9, fig. 17, is registered as No. 89466 in the Geological Survey and Museum. The metastoma figured on Text-figure 3, fig. 36, is registered as 89359 in the collections of the Geological Survey and Museum, London. The other metastoma described above is registered as In 44581 in the British Museum (Natural History).

ERETTOPTERUS (TRUNCATIRAMUS) GIGAS MEGALODON Kjellesvig-Waering, n. ssp.
Pl. 96, fig. 1; text-fig. 3, fig. 41

Pterygotus problematicus STRICKLAND, 1852, p. 384; SALTER, 1852, p. 386, figs. 1,2; SYMONDS, 1856, p. 99; BANKS, 1856, p. 93; WOODS, 1891, p. 153.

The chelicera to be described is, historically, one of the earliest and best known pterygotids. It was reported by Strickland and described by Salter in 1852 as the chela and gnathobase of *Pterygotus problematicus* Agassiz when that species was considered valid. As explained on page 812 of this report, the specimen cannot be identified as *Pterygotus problematicus* Agassiz as that species was based on undiagnostic parts which may represent one or more genera and one or more of a half dozen known species of pterygotids. As such, therefore, the name *Pterygotus problematicus* Agassiz was considered *nomen vanum* and was discarded.

The chelicera described by Strickland and Salter, however, clearly is a diagnostic part of a pterygotid and remains without a name. Inasmuch as this species represents the only species of the subgenus *Truncatiramus* in the Upper Ludlow, it is an important constituent of that fauna and is herein described as a subspecies of *E.* (*Truncatiramus*) *gigas*, and named *megalodon* because of the unusually large central tooth in the fixed ramus of the chelicera.

The holotype (see Pl. 96, fig. 1) is the specimen which Salter used in his 1852 description which comprises an articulated chelicera retaining the central parts of both the free and fixed rami rather than a ramus and gnathobase of a coxa as Salter indicated. The main characteristic (see Text-fig. 3, fig. 41) of the species is the central tooth of the fixed ramus which indicates close relationship with *E.* (*T.*) *gigas gigas* (Salter) of the overlying Downtonian beds. It is, as in the latter, serrated along the inner edge of the tooth and these serrations are evenly spaced on the tooth and at 90°, more or less, to the tooth. This tooth is followed on either side by irregular sized teeth which are more spine-like and longer than those on the Downtonian form. At the posterior part of the free ramus is a diagonal tooth which juts outward from the base of the free ramus. This reveals a harpoon-like projection, which probably is due to preservation rather than actually being a morphological structure. All teeth are reinforced with linear ridges, the so-called striations, commonly found in all mature pterygotids.

The free ramus reveals a tooth which opposes the large central tooth of the fixed ramus. This is larger than the adjacent teeth and is perpendicular to the ramus but does not reveal serrations. The adjacent teeth are much smaller, also sharply pointed, irregular in size and longer than those occurring on the free ramus of *Erettopterus* (*Truncatiramus*) *gigas gigas*. In comparison, also, the free ramus of *E.* (*T.*) *gigas megalodon* is much thicker at the position of the central tooth than it is in *E.* (*T.*) *gigas gigas*. This ramus also is probably longer, comparatively, than the tapered ramus of *E. T. gigas gigas*. The main differences between the two subspecies are readily apparent in comparison of the arrangement of the teeth.

Horizon and locality.—The species is known only from the holotype. This specimen was discovered by Mackay Scobie about 1850 in the Upper Ludlow, Bed 10, below the Ludlow Bone Bed in shale associ-

ated with *Avicula retroflexa*, *Orthis lunata* and *Orbicula rugata*, a few hundred yards west of Hagley House, Lugwardine, Herefordshire, England.

Repository.—The holotype is registered as No. 48045 to 48048 in the Strickland collection of the Sedgwick Museum, Cambridge University.

Family EURYPTERIDAE Burmeister, 1845
Genus EURYPTERUS DeKay, 1825
EURYPTERUS CEPHALASPIS Salter
Pl. 95, fig. 10; text-fig. 1, figs. 13–19

Homalonotus (?) *cephalaspis* SALTER *in* Burmeister, 1846, p. 125 (*nomen nudum*).

Eurypterus cephalaspis SALTER *in* Sedgwick & McCoy, 1855, p. v, pl. 1E, fig. 21; McCOY *in* Sedgwick & McCoy, 1855, p. 175; BIGSBY, 1859, p. 321; WOODWARD, 1877, p. 64; ETHERIDGE, 1888, p. 52; O'CONNELL, 1916, p. 39; KING, 1934, p. 563; KJELLESVIG-WAERING, 1958, p. 1121.

Eurypterus linearis SALTER, 1859, p. 234, p. 10, figs. 16, 16a and b; BIGSBY, 1859, p. 321; WOODWARD, 1864, p. 107; ——, 1866–1878, p. 147–148, pl. 28, figs. 10–12; MARSTON, 1870, p. 407; WOODWARD, 1877, p. 65; SCHMIDT, 1883, p. 50; ETHERIDGE, 1888, p. 53; LAURI, 1895, p. 158; ELLES & SLATER, 1906, p. 220; O'CONNELL, 1916, p. 40; DIENER, 1924, p. 17; KING, 1934, p. 563.

Eurypterus pygmaeus BANKS, 1856, p. 99, p.. 11, fig. 4b.

Eurypterus brodiei WOODWARD, 1871, p. 261–263, fig. 1 (not figs. 2 and 3); ——, 1871a, p. 161–163, fig. 53; ——, 1877, p. 64; ETHERIDGE, 1888, p. 52; WOODWARD, 1907, p. 278; O'CONNELL, 1916, p. 39; DIENER, 1924, p. 16; KING, 1934, p. 563; STØRMER, 1934, p. 19; ——, 1936, p. 33; KJELLESVIG-WAERING, 1951, p. 17–21, pl. 3, fig. 1, text-fig. 21.

Hughmilleria linerais STØRMER, 1934b, p. 6.

Hughmilleria (?) *linearis* STØRMER, 1934, p. 83; KJELLESVIG-WAERING, 1950, p. 238.

The holotype, which comprises a carapace from the Downtonian of Kirkby Moor, Kendal, Westmoreland, was intended to be described as a trilobite by Salter, as the genus *Eurypterus* was practically unknown in Britain at the time. Later, in 1855, he recognized the true nature of the specimen and named it *Eurypterus cephalaspis*. The name, however, did not become definitely established and little was further learned about this species. In 1859 Salter described parts of three telsons from the Downton sandstone at Kington and, doubtfully, from the Upper Ludlow of Ludford Lane, Ludlow, Shropshire. This species was named *Eurypterus linearis* and remained known from only the telsons until the present time. In 1871, Woodward described a new species under the name *Eurypterus brodiei* from the lower Downtonian at Perton, Herefordshire and Kjellesvig-Waering (1951) described additional specimens of the latter species from the same locality and corrected some misconceptions with regard to Woodward's original description which had included some specimens of *Hughmilleria banksii*.

It is possible now, with considerable material mainly from the Banks, Marston and Lightbody collections, made about 1855–1860, as well as some recently collected specimens, to show that all three aforementioned species represent a single form, namely *Eurypterus cephalaspis* Salter, which has clear priority over the other two specific names (*Eurypterus linearis* Salter and *Eurypterus brodiei* Woodward).

In the material studied it was possible to determine specimens which retained enough parts to tie into the telson (only part known) of *Eurypterus linearis* and into *Eurypterus brodiei*. One specimen (In 44557) retained the telson of *E. linearis* and fortunately the rest of the body of an *Eurypterus brodiei*. This same specimen also retained the thick marginal rim of *Eurypterus cephalaspis* (see Text-fig. 17). Likewise, specimen 89473, preserved nearly whole, revealed the characteristics of these three eurypterids and proved beyond question that all three represented a single species. Seven carapaces also reveal no differences with the carapace described as the holotype of *Eurypterus cephalaspis*.

Measurements of the carapace:

Specimen number:	Width at base:	Length:
89425 b	12.7 mm.	8.4 mm.
89445	14.2 mm. (est.)	10.8 mm.
89473	14.7 mm.	9.9 mm.
89484	15.2 mm.	11.0 mm.
89425 a	15.7 mm.	11.5 mm. (est.)
B.U. 29	16.0 mm.	11.0 mm.
In 44574	16.5 mm.	11.3 mm.

The last specimen in the above series has lateral eyes which measure 3.0 mm. in length.

A specimen (PE 5124) consisting of the telson and associated with *E.* (*Erettopterus*)

spatulatus, reveals the original coloration of the telson, and it is likely that the rest of the body of this species was of the same color. See page 823 under description of *E.* (*Eretopterus*) *spatulatus* for details of coloration.

The telson figured by Salter (1859, p. 234, pl. 10, fig. 16a) as one of the types of *Eurypterus linearis* is specimen No. 89426 in the collection of the Geological Survey and Museum, and is here figured in Text-figure 1, fig. 18. This specimen actually is the holotype of the species *E. linearis*, inasmuch as fig. 15 was introduced as a variation. The telson here figured in Text-figure 1, fig. 18 measured 28.7 mm. in estimated length and 6.4 mm. in greatest length.

Horizon and locality.—Except for one doubtful record, the species is restricted to the Downtonian. It is the writer's opinion that the doubtful record should be disregarded. This comprised one of the types of *Eurypterus linearis* which was labeled Upper Ludlow (?), Ludford Lane. The other two types of the same species came from the Downtonian at Kington, Herefordshire. The holotype of *Eurypterus cephalaspis* Salter is from the Downtonian at Kirkby Moor, Kendal, Westmoreland. The writer has identified this form as follows: 89425 a and b, two specimens from the Downtonian at Ludford Lane, Ludlow, Shropshire, collected by Robert Lightbody, 1858–59; 89445 from the Downton Sandstone at Onibury, 5 miles N.W. of Ludlow, Shropshire; 89473 Downtonian at Kington, Herefordshire; 89484 from the Downtonian at Kington, Herefordshire; In 44557 from the Temeside shale at the Ludlow railway cutting, Ludlow, Shropshire, collected by Robert Lightbody about 1858; In 44570 from the base of the Downton Sandstone at Ludford Lane, Ludlow, Shropshire, collected by Robert Lightbody, about 1858; In 44574, same horizon and locality; In 44576, from the Downton sandstone, same locality as previous; BU 22 and BU 29, from the Downtonian at Bradnor Hill, Kington, Herefordshire; PE 5124, from the Temeside shales (olive shales), at Tin Mill Race, near Downton Castle, Herefordshire, collected by Robert H. Denison. Aside from these records, he has further identified numerous specimens from the lower Downtonian at Perton, near Stoke Edith, Herefordshire as *Eurypterus brodiei* Woodward (Kjellesvig-Waering, 1951, p. 17–21).

Repository.—Specimens Nos. 89425 to 89484 are in the Geological Survey and Museum, London; Specimens In 44557 to In 44576 are in the collection of the British Museum; BU 22 and BU 29 are in the Geological Museum, Birmingham University, Birmingham, England, and PE 5124 is in the Chicago Natural History Museum collections.

Family CARCINOSOMATIDAE Størmer, 1934

Genus CARCINOSOMA Claypole, 1890

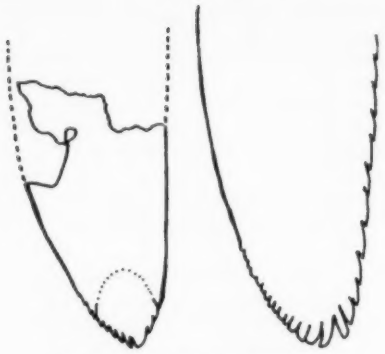
CARCINOSOMA HARLEYI Kjellesvig-Waering, n. sp.

Text-fig. 4, left figure

Pterygotus punctatus SALTER, 1859, pl. 12, fig. 19; pl. 13, figs. 5,6 and 9(?).

The presence of a *Carcinosoma* in the Upper Ludlow has been known for a considerable time. Salter reported several fragments in 1859, pl. 12, fig. 19, and pl. 13, figs. 5,6 and possibly fig. 9, which were referred to what is now known as *Carcinosoma punctatum*. Woodward also reported the same species from the Upper Ludlow (1866–1878, p. 159) although he did not figure any specimens. All these fragments comprised mainly undiagnostic patches of the integument and leg joints of *Carcinosoma*, and because no other carcinosomatid was known from the Welsh Borderland, they were unquestionably referred to *C. punctatum*. Of all these specimens, only one can be considered as being of diagnostic value, and this fortunately represents the end of the swimming leg paddle which is one of the most diagnostic parts among the superfamily Eurypteracea. This specimen was figured by Salter as *C. punctatum* (1859, pl. 12, fig. 19). It retains the distal half of the seventh and all of the eighth joints, and is here refigured on Text-figure 3, fig. 46. It has been named in honor of John Harley of King's College, one of the early collectors of eurypterids in the Welsh Borderland.

The species is a large form. The holotype is a fragment of the swimming leg which measured 50.0 mm. in length. The seventh joint is nearly straight along the posterior edge. The eighth joint is faintly visible on the edges of the paddle, but is not visible



TEXT-FIG. 4—Details of Silurian eurypterid morphology.

Carcinosoma harleyi n. sp., ×1, holotype (on left). The distal part of the swimming leg. From the Upper Ludlow, at Whitcliffe, Shropshire, England. Specimen No. 89434 in the Geological Survey and Museum, London.

Carcinosoma punctatum (Salter), ×2, lectotype (on right). The distal part of the swimming leg. From the Middle Ludlow, Mocktree shale at Leintwardine, Herefordshire, England. Specimen No. 89435 in the Geological Survey and Museum, London.

away from the edges. However, it is evidently a large structure in keeping with other carcinosomatids. The few serrations present in this form occur along the extremities of this joint. The widest part of the seventh joint measures 26.0 mm. but it probably reached 28.0 mm. in reconstructed width.

Repository.—Registered as No. 89434 in the collection of the Geological Survey and Museum (London).

Horizon and locality.—Associated on the same bedding plane with articulate brachiopods, in hard greenish gray dolomitic shale. Upper Ludlow, at Whitcliffe, Ludlow, Shropshire, England; collected by Alfred Marston, about 1858.

Remarks.—The species is very distinct. It differs from the underlying Middle Ludlovian, *C. punctatum* (Salter), in the nearly complete lack of serrations along the extremities of the seventh (tarsus) joint, and in the far lesser development of these serrations on the eighth (transtarsus) joint. The differences are readily apparent in a comparison of the holotype of *C. harleyi* on Text-figure 4, left figure, with the lectotype of *C. punctatum* in Text-figure 4, right figure.

CARCINOSOMA PUNCTATUM (Salter)
Text-fig. 3, figs. 42–45; Text-fig. 4, right figure

Pterygotus punctatus SALTER, 1859, pl. 10, figs. 1–9,10(?),11(?); pl. 11, figs. 5–9,12–15; pl. 13, fig. 14; text-fig. 14; BIGSBY, 1859, p. 322; HUXLEY, 1859, p. 21; WOODWARD, 1868, p. 290; ——, 1866–1878, p. 153–159, figs. 49–51, pl. 24, fig. 2; ——, 1877, p. 65; ETHERIDGE, 1888, p. 53; FRAIPONT, 1889, p. 62; LAURIE, 1899, p. 587; GEIKIE, 1903, p. 958; SARLE, 1903, p. . 1108; SEEMANN, 1906, p. 55; WOODWARD, 1909, p. 486; DIENER, 1924, p. 18; VĂSCĂUTANU, 1932, p. 616; KING, 1934, p. 563.
Eusarcus punctatus CLARKE & RUEDEMANN, 1912, p. 231, fig. 52; O'Connell, 1916, p. 43.
Stylonurus punctatus ETHERIDGE, 1888, p. 146.

Not *Carcinosoma punctatum* (Salter)

Pterygotus punctatus SALTER, 1859, pl. 11, figs. 1,2,3; pl. 13, fig. 7 (= *Erettopterus marstoni*).
Pterygotus punctatus SALTER, 1859, pl. 11, fig. 4 (= *Salteropterus* (?) *longilabium*).
Pterygotus punctatus SALTER, 1859, pl. 12, fig. 18 (= indeterminable pterygotid).
Pterygotus punctatus SALTER, 1859, pl. 12, fig. 19; pl. 13, figs. 5,6,9(?) (= *Carcinosoma harleyi*).
Pterygotus punctatus POWRIE, 1864, p. 415, (= *Pterygotus anglicus* Agassiz ?).

This species was established by Salter (1859) upon a syntypic series of detached fragments representing some of the prosomal appendages, parts of the mesosoma and the median appendage. In the original description, the specimens figured on pl. 10, fig. 1–9, represent this species, although figures 10 and 11 are indeterminable fragments. His pl. 11, figs. 1,2 and 3 have been here designated as *Erettopterus* (*Erettopterus*) *marstoni*. These had been previously correctly recognized by Woodward (1866–78) as the chelicera of a pterygotid. Fig. 4 of the same plate has been made the holotype of *Salteropterus* (?) *longilabium* Kjellesvig-Waering, n. sp. Figs. 5 to 9 and 12 to 15 on pl. 11 of Salter's (1859) monograph properly represent parts of *C. punctatum*. On pl. 12, figs. 18,19 of the same paper are the distal joints of two swimming paddles which do not represent this species. Both specimens are from the Upper Ludlow at Ludlow. Fig. 18 is probably a pterygotid but figure 19 has been designated as the holotype of *Carcinosoma harleyi* Kjellesvig-Waering, n. sp., the original of which was available for this

study. The specimens figured on pl. 13, figs. 5,6 represent undiagnostic fragments, very likely *Carcinosoma harleyi*, whereas the original of fig. 7 has been referred here to *Erettopterus marstoni* (mislabeled on Salter's plate as being from the Upper Ludlow. The original label, glued to the specimen, reveals that it is from the Mocktree Shale at Leintwardine). On this same plate, fig. 9 represents a walking leg which will have to be studied from the original material before it can safely be referred to any known species. It may represent *C. harleyi*. Fig. 14 of the same plate is the coxa of the walking leg of *C. punctatum*.

Available for this study have been numerous specimens of this species. Among the more important ones is specimen 89435, which represents one of Salter's (1859) specimens having been figured on pl. 11, fig. 14, of the original description. This specimen is hereby designated as the lectotype. Several specimens of the first walking leg and one of the chelicera, as well as a specimen retaining all the swimming leg joints, add new morphological details hitherto undescribed. The chelicera is shown in Text-figure 3, fig. 42, which comprises a simple pincer retaining the last two joints. The following are the measurements of this specimen (No. 89581):

Second joint:	
greatest width:	10.5 mm.
length through center:	16.0 mm.
overall length of part preserved:	28.9 mm.
overall length restored:	30.8 mm.
Third joint:	
width at base:	5.3 mm.
inside length of part preserved:	11.0 mm.
inside length restored:	12.5 mm.

The first walking leg comprises a coxa followed by six joints, the last of which is a terminal spine. This is a distinct and unusual structure. The coxa is nearly circular in outline, having at the inner edge a large triangular tooth which represents the first or outside tooth of the mouth. This is followed by a decreasing series of backwardly directed long, thin teeth. The teeth at the inner extremity appear almost as if they were small bristles. The coxa is followed by six joints, the last of which is a spine. The unique feature of the walking leg is the presence of an unusually stout spine on the second joint. This feature has not been noted in other eurypterids, although it might have a clasping function as has been noted in reference to the first walking leg of *Eurypterus* (Holm, 1898) and *Mixopterus* (Størmer, 1934). The stout spine is ornamented with a series of pits on the sides indicating that this spine was a very flat organ and was not round in cross section as are other spines.

Measurements of first walking leg:

Specimen No. 89565:	
overall length measured on the outside curve:	55.5 mm.
width of second joint:	7.0 mm.
width of thick spine on second joint:	5.4 mm.
estimated length:	8.0 mm.
Specimen No. 89583:	
width of thick spine:	9.3
length of spine on third joint:	15.5 mm.

The swimming leg is represented by two specimens, No. 89561, which was a young form and nearly retains all the joints, and the lectotype, which was a large adult and included only the sixth, seventh and eighth joints. In neither specimen has it been possible to determine the outlines of the distal joint although it is present. The lectotype, No. 89435, was the subject of Salter's 1859 pl. 11, fig. 14, which is accurate except in minor details regarding the serrations at the distal end. This part is here reproduced on Text-figure 3, fig. 47.

Measurements of specimens:

Specimen No. 89561:	
width of seventh joint:	8.7 mm.
width of sixth joint:	11.5 mm.
overall length of entire leg on the curve:	63.0 mm.
Specimen No. 89435 (lectotype):	
width of seventh joint:	31.5 mm.
width of sixth joint:	45.5 mm.

Horizon and locality: The above specimens are from the Middle Ludlow, Mocktree shales, at Leintwardine, Herefordshire, England. The species has been previously reported from beds ranging in age from the Wenlock to the Upper Ludlow. Records that are verified by photographs, or other figures, reveal that this species is unknown except from the Middle Ludlow and that all other records are based on undiagnostic fragments of the integument which reveal nothing more than the presence of Carcinosomatidae or Mixopteridae.

Repository.—Specimens 89435 (lectotype), 89565, 89581, 89583 are in the collection of the Geological Survey and Museum (London).

Remarks.—This is one of the giants among the eurypterids. The metastoma figured by Woodward (1866–1878, text-fig. 50) measures 5 inches in length. This would indicate that the individual reached a total length, from the anterior end of the carapace to the posterior end of the telson, of approximately 2.2 meters in length. The prosomal appendages in the natural, unextended position would increase this to an overall length of about 2.5 meters. This is considerably larger than any other known carcinosomid, and rivals some of the pterygotids in size. This distinct species can be easily recognized by the details of the prosomal appendages. It differs from the Upper Ludlow *Carcinosoma harleyi* in the greater development of serrations on the distal end of the swimming leg paddle.

CARCINOSOMA (?) sp. Kjellesvig-Waering

Carcinosoma sp. KJELLESVIG-WAERING, 1951, p. 21, text-fig. 1, figs. 2J,K,L.

A single fragment of the integument was recorded. No further specimens known.

EXPLANATION OF PLATE 95

FIG. *1*—*Parahughmilleria salteri* Kjellesvig-Waering, n. sp., ×3.2. A carapace, preserved in sandstone in an uncrushed and undistorted condition. From the Downston sandstone, Bradnor Hill, Kington, Herefordshire, collectec by Richard Banks about 1850. Specimen No. In 43776 in the British Museum (Natural History).

2—*Parahughmilleria salteri* Kjellesvig-Waering, n. sp., ×3.7. A carapace preserved in sandstone and retaining original outline. From the base of the Downton sandstone, at Ludford Lane, Herefordshire, England; collected by Robert Lightbody, 1858–1859. Specimen No. In 44573 in the British Museum (Natural History).

3—*Parahughmilleria salteri* Kjellesvig-Waering, n. sp., ×5. A distorted carapace preserved in olive shale. From the Temeside shale, at the railway cutting, Ludlow, Shropshire, England, collected by Robert Lightbody, about 1858. Specimen No. In 44561 in the British Museum Natural History).

4—*Parahughmilleria salteri* Kjellesvig-Waering, n. sp., ×5.5. The metasomal tergites and telson. This specimen was figured by Salter (1859, pl. 10, fig. 6) and Woodward (1866–78, pl. 28, fig. 7). From the Downtonian at the railway cutting, Ludlow, Shropshire, England; collected by Robert Lightbody, 1858–59. Specimen No. 89386 in the Geological Survey and Museum, London.

5—*Parahughmilleria salteri* Kjellesvig-Waering, n. sp., ×3.5. The holotype; an undistorted operculum and female median appendage preserved in olive shale. Details are shown in Text-figure 1, fig. 11. From the Downtonian at the railway cutting, Ludlow, Shropshire, England; collector is unknown. Specimen No. 89391 in the Geological Survey and Museum, London.

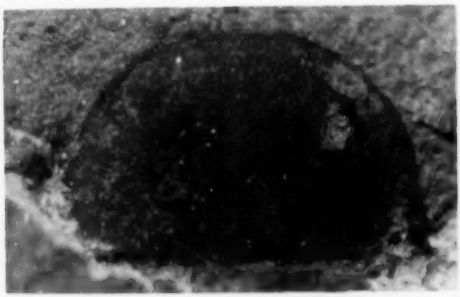
6—*Stylonurus megalops* (Salter), ×2.3. The lectotype which comprises a well preserved mold of the anterior part of the carapace. See reconstruction on Text-figure 2, fig. 26. This specimen was figured by Salter (1859, pl. 10, fig. 9) and by Woodward (1866–78, pl. 21, fig. 3). From the Downtonian at the railway cutting, Ludlow, Shropshire, England. Specimen No. 89403 in the Geological Survey and Museum, London.

7—*Dolichopterus bulbosus* Kjellesvig-Waering, n. sp., ×1.5. The holotype, a carapace, details of which are shown in Text-figure 1, fig. 21. From the Temeside shale at the railway cutting, Ludlow, Shropshire, England; collected by Robert Lightbody, about 1858. Specimen No. In 44565 in the British Museum (Natural History).

8—*Hughmilleria* (*Nanahughmilleria*) *pygmaea* (Salter), ×4. A carapace, details of which are reconstructed on Text-figure 1, figs. 4 and 5. From the Downtonian at the railway cutting, Ludlow, Shropshire, England. Collected by Robert Lightbody, about 1858. Specimen No. 18383 in the Geological Survey and Museum, London.

9—*Hughmilleria* (*Hughmilleria*) (?) *acuminata* (Salter), ×0.7. The holotype. A telson preserved in olive shale. From the railway cutting, Ludlow, Shropshire, England; collected by Alfred Marston, about 1858. Specimen No. 89404 in the Geological Survey and Museum, London.

10—*Eurypterus cephalaspis* Salter, ×1.6. A telson preserved in olive shale and retaining original coloration. The overall color is dark brown with black on the fringes. From the Temeside shale at Tin Mill Race, Downton Castle, Herefordshire, England; collected by Robert H. Denison. Specimen No. PE 5124 in the Chicago Natural History Museum.

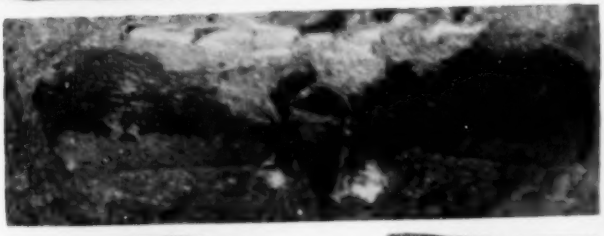


1

2

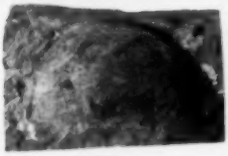
3

4



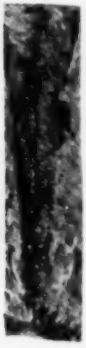
5

6



7

8



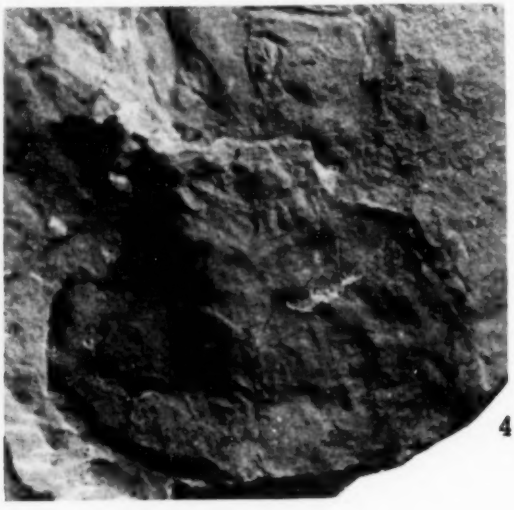
10

9

1

2

3



4

Horizon and locality. Lower Downtonian, at Perton, near Stoke Edith, Herefordshire, England.

Family MIXOPTERIDAE Caster & Kjellesvig-Waering, 1955
Genus MIXOPTERUS Ruedemann, 1921
MIXOPTERUS sp. Kjellesvig-Waering, 1951

Mixopterus sp. KJELLESVIG-WAERING, 1951, p. 21,22, text-fig. 2C.

A leg of a small *Mixopterus* was recorded. No other specimens known.

Horizon and locality.—Lower Downtonian, Perton, Herefordshire, England.

MIXOPTERUS (?) sp.

A metasomal tergite, measuring 50 mm. in length, indicates the presence of a *Mixopterus* or a *Carcinosoma* in the Wenlock beds. A more diagnostic part is needed for identification. The tergite retains elongated, raised, linear sculpturing characteristic of *Mixopterus*, although the possibility of its being a *Carcinosoma* must be admitted.

Horizon and locality.—Preserved in dark gray, soft shale, and associated with articulate brachiopods and fragments of trilobites. Wenlock beds at Garcoed, near Usk, Monmouthshire, England.

Repository.—No. 36406 in the Geological Survey and Museum, London.

Superfamily STYLONURACEA Diener, 1924
Family DOLICHOPTERIDAE Kjellesvig-Waering & Størmer, 1952
Genus DOLICHOPTERUS Hall, 1859

DOLICHOPTERUS BULBOSUS Kjellesvig-Waering, n. sp.
Pl. 95, fig. 7; text-fig. 1, fig. 21

The species is based on a single carapace, well preserved in an uncrushed but slightly distorted condition. It is surprising that the Downtonian beds still reveal undescribed forms, but it was entirely expected that *Dolichopterus* should occur in the British Silurian, inasmuch as it occurs with other genera present in North America and Oesel (Saaremaa) and well represented in Britain.

The carapace is bulbous, subovate in general outline, and has a narrow marginal rim developed that surrounds the carapace. The base is truncated, and the genal angles form nearly a 90 degree angle with the lateral margins. The lateral eyes are placed intramarginally, well forward on the carapace, and are elongate-reniform in outline. The ocelli occur with the lateral eyes and are located midway between, and at the poste-

EXPLANATION OF PLATE 96

FIG. 1—*Erettopterus* (*Truncatirmaus*) *gigas megalodon* Kjellesvig-Waering, n. ssp., ×1. The holotype, consisting of the chelicera. From the Upper Ludlow, Bed 10, below the Ludlow Bone Bed, a few hundred yards west of Hagley House, Lugwardine, Herefordshire, England, and associated on the same slab with numerous specimens of *Avicula retroflexa*. This specimen has been previously figured, as a drawing, by Salter in 1852, (p. 386, figs. 1,2). Registered as specimen No. 48045 to 48048 in the Strickland collection of the Sedgwick Museum, Cambridge University. Photograph by C. L. Forbes.

2—*Salteropterus* (?) *longilabium* Kjellesvig-Waering, n. sp., ×1. The holotype from the Middle Ludlow, Mocktree shales at Church Hill, Leintwardine, Herefordshire, England; collected by Alfred Marston, about 1855. This metastoma was previously figured, as a drawing, by Salter, 1859, pl. XI, fig. 4. Registered as No. 39386 in the British Museum (Natural History). Photograph (negative No. 252181) by the British Museum (Natural History).

3—*Erettopterus* (*Erettopterus*) *spatulatus* Kjellesvig-Waering, n. sp., ×5.5. This carapace is the counterpart of Pl. 94, fig. 5. The bulbous eyes, which have been partly mashed, and the ocellar mound are particularly well preserved. From the Downton sandstone at Ludford Lane, Shropshire, England. Specimen No. In 43794 in the British Museum (Natural History).

4—*Erettopterus* (*Erettopterus*) *spatulatus* Kjellesvig-Waering, n. sp., ×2.6. The holotype; the telson enlarged; for details see Text-fig. 25. This specimen has also been figured on Pl. 94, fig. 4. From the Downtonian at the railway cutting, Ludlow, Shropshire, England; collected by Robert Lightbody, 1858–59. Specimen No. 89397 in the Geological Survey and Museum; counterpart (In 44563) in the British Museum (Natural History).

rior extremity of the lateral eyes. They do not occur on any noticeable ocellar mound.

Measurements of the holotype:

Carapace:	Width at base:	Length:
	15.6 mm.	25.0 mm.

The lateral eyes are 5.2 mm. in length, 2.5 mm. in greatest width, and are located on the carapace 1.4 mm. from the lateral margin 9.5 mm. from the base, and 2.8 mm. from the anterior margin. They are 12.7 mm. apart at their posterior extremities, and approximately 9.0 mm. apart at the anterior. The ocelli are very small, approximately 0.5 mm. in diameter, 0.5 mm. apart, and are located on the prosoma 6.0 mm. from the anterior margin, approximately 9.0 mm. from the base, and 9.0 mm. from the lateral margins.

Horizon and locality.—Downtonian, Temeside shale. The holotype is preserved in sandy gray shale. Collected at the railway cutting, Ludlow, Shropshire, England, by Robert Lightbody about 1858. The species is known only from one specimen.

Repository.—Holotype is registered as No. In 44565 in the collection of the British Museum (N. H.).

Remarks.—The only known European form of this genus is *Dolichopterus størmeri* Caster & Kjellesvig-Waering from the Oesel fauna, a form which is close to the genotype *D. macrocheirus* Hall, from the Williamsville dolomite (Upper Bertie) of New York. The new species differs from the genotype in having the prosoma less quadrate, the eyes more subreniform rather than arcuate, and the ocelli placed more anteriorly on the carapace.

Family STYLONURIDAE Diener, 1924

Genus STYLONURUS Page, 1856

STYLONURUS MEGALOPS (Salter)

Pl. 95, fig. 6; text-fig. 2, fig. 26

Eurypterus megalops SALTER, 1859, p. 233–234, pl. x, figs. 9,10,11,12 (not 13 and 14); BIGSBY, 1859, p. 321; MARSTON, 1870, p. 409; ELLES & SLATER, 1906, p. 220; KING, 1934, p. 563.
Eurypterus ? megalops WOODWARD, 1864, p. 107.
Stylonurus megalops WOODWARD, 1865, p. 486; ——, 1872 (1866–1878) p. 124, pl. 21, figs. 3, 3a; ——, 1877, p. 69; ETHERIDGE, 1888, p. 68 (not p. 146); CLARKE & RUEDEMANN, 1912, p. 288; O'CONNELL, 1916, p. 48; DIENER, 1924, p. 23; STØRMER, 1934a, p. 101; KJELLESVIG-WAERING, 1958, p. 1141.

Not *Stylonurus megalops* (Salter)

Eurypterus megalops SALTER, 1859, pl. 10, figs. 13,14 = *Hughmilleria banksii* (Salter).
Stylonurus megalops WOODWARD, 1872 (1866–1878), pl. 28, figs. 8,9 = *Hughmilleria banksii* (Salter).

The species was described by Salter from a syntypic series which included fragments of three carapaces, a metasoma with attached telson and a separate telson. The metasoma and telson is specimen No. 89400 in the collections of the Geological Survey and Museum (counterpart is In 44584 in the British Museum) and the separate telson is registered as No. 89405 in the Geological Survey and Museum collection. Both these specimens were figured by Salter, 1859, pl. 10, figs. 13 and 14 respectively, as the caudal area of this species. Both were later figured by Woodward as the same species (1872, pl. 28, figs. 8 and 9). Both specimens, however, undoubtedly belong to *Hughmilleria banksii* (Salter). The only part known of *Stylonurus megalops* is the carapace and this is known only by the parts of three carapaces figured by Salter (1859, pl. 10, figs. 9,10 and 11). The lectotype is herein designated as the carapace used in Salter's fig. 9, which is registered as No. 89403 in the collection of the Geological Survey and Museum. Salter's fig. 11 is registered as No. 89406 in the same institution. Both these specimens were available to the writer and constitute the basis of the reconstruction on Text-figure 2, fig. 26. The genal angles of the carapace still remain unknown. The nearly circular, or highly arcuate, eyes are an extreme development for *Stylonurus* and it is entirely possible that more material will reveal this as an undescribed genus of the Stylonuridae.

Horizon and locality.—All three specimens known are from the Downtonian at the railway cutting, Ludlow, Shropshire.

Repository.—The lectotype, subject of Salter's 1859, pl. 10, fig. 9, and refigured by Woodward 1872 (1866–1878), pl. 21, fig. 3, is registered as No. 89403 in the Geological Survey and Museum, London. The paratype, figured by Salter, 1859, pl. 10, figs. 11 and 12, and by Woodward, 1872 (1866–1878), pl. 21, fig. 3a, is registered as No. 89406 in the same institution.

Genus TARSOPTERELLA Størmer, 1951
TARSOPTERELLA (?) sp. Kjellesvig-Waering

Tarsopterus (?) sp. KJELLESVIG-WAERING, 1951, p. 22, pl. 3, figs. 3,4.

A single specimen of a fragmentary coxa and attached first joint of the sixth appendage was referred with doubt to *Tarsopterella*. It is, however, possible that this might be part of *Salteropterus abbreviatus* (Salter). No additional specimens are known.

Horizon and locality.—Lower Downtonian at Perton, near Stoke Edith, Herefordshire, England.

Genus MARSUPIPTERUS Caster & Kjellesvig-Waering, 1955
MARSUPIPTERUS SCULPTURATUS Caster & Kjellesvig-Waering

Marsupipterus sculpturatus CASTER & KJELLESVIG-WAERING, 1955, p. 1040–1041, text-fig. 1.

This unique and unusual form remains known only from the holotype which comprises a telson having a large ventral opening which probably was cloacal in function. Like *Slimonia* (?) *stylops* Salter, *Hughmilleria acuminata* (Salter), *Stylonurus megalops* (Salter) and *Salteropterus abbreviatus* (Salter), it is one of the rarer, more problematical forms, and one of the reasons why the highly diversified Downtonian eurypterid fauna of England is second to none in interest and importance.

Horizon and locality.—Downtonian: Downton Castle sandstone at Forge Bridge, Downton, Shropshire, England.

Repository.—Registered as No. 89467 in the Geological Survey and Museum, London, England.

REFERENCES

AGASSIZ, L., 1839, *in* R. I. Murchison, The Silurian System, founded on Geological Researches, etc.

——, 1844, Monographie des poissons fossiles du Vieux Gres Rouge, ou Système Devonien. Neufchatel, folio.

ALEXANDER, F. E. S., 1936, The Aymestry limestone of the main outcrop: Q.J.G.S., London, v. 92, p. 103–115, pl. 8.

BALL, H. W., 1951, The Silurian and Devonian rocks of Turner's Hill and Gornal, south Staffordshire: Proc. Geol. Assoc., v. 62, p. 225–236.

BANKS, R. W., 1856, On the Tilestones or Downton sandstones, in the neighbourhood of Kington, and their contents: Q.J.G.S., London, v. 12, p. 93–102, 1 pl.

BIGSBY, J. J., 1859, An inquiry into the sedimentary and other external relations of the Palaeozoic fossils of the State of New York: Q.J.G.S., v. 15, p. 251–335.

BRODIE, P. B., 1869, On the occurrence of remains of *Eurypterus* and *Pterygotus* in the Upper Silurian rocks of Herefordshire: Q.J.G.S., London, v. 25, p. 235–237.

——, 1871, On the "Passage-beds" in the neighborhood of Woolhope, Herefordshire, and on the discovery of a new species of *Eurypterus*, and some land-plants in them: Geol. Mag., v. 8, p. 230.

BURMEISTER, H., 1846, The organization of trilobites deduced from living affinities with a systematic review of species hitherto described: Ray Soc., 136 p.

CASTER, K. E. & KJELLESVIG-WAERING, E. N., 1955: *Marsupipterus*, an unusual eurypterid from the Downtonian of England: Jour. Paleontology, v. 29, no. 6, p. 1040–1041.

CLARKE, J. M. & RUEDEMANN, R., 1912, The Eurypterida of New York: New York State Mus., Mem. 14, p. 1–439, 88 pls.

CLAYPOLE, E. W., 1890, Palaeontological notes from Indianapolis: Amer. Geologist, v. 6, p. 255–260.

DENISON, R. H., 1956, A review of the habitat of the earliest vertebrates: Fieldiana: Geology, v. 11, no. 8, p. 359–457.

DIENER, C., 1924, Fossilium Catalogus, I: Animalia. Pars 25: Eurypterida: p. 1–29, 8vo. Berlin.

ELLES, G. L. & SLATER, I. L., 1906, The highest Silurian rocks of the Ludlow District: Q.J.G.S., London, v. 62, p. 195–222, 1 pl.

ETHERIDGE, R., 1888, Fossils of the British Islands stratigraphically and zoologically arranged, v. 1, Palaeozoic.

FRAIPONT, J., 1889, Eurypterides nouveaux du Dévonien supérieur de la Belgique: Ann. soc. Géol. Belgique, v. 17, p. 53–62, pl. 2.

HALL, J., 1859, Palaeontology of New York, v. 3, pt. 1–2, 532 p., 120 pls.

HARLEY, J., 1861, On the Ludlow Bone-bed and its crustacean remains: Q.J.G.S., London, v. 17, p. 542–552, pl. 17.

HUXLEY, T. H. & SALTER, J. W., 1859, On the anatomy and affinities of the genus *Pterygotus* and description of new species of *Pterygotus:* Mem. Geol. Surv., United Kingdom, Monogr. 1, 105 p., 16 pls.

KIAER, J., 1911, A new Downtonian fauna in the sandstone series of the Kristiania area: A preliminary report: Videnskr.-selsk. Skrifter, Kristiania, 1911, no. 7, p. 1–22.

KING, W. W., 1912, The Uppermost Silurian and Old Red Sandstone of South Staffordshire: Geol. Mag., dec. 5, v. 9, p. 437–443.

——, 1934, The Downtonian and Dittonian strata of Great Britian and North-Western Europe: Q.J.G.S., London, v. 90, p. 526–566.

KJELLESVIG-WAERING, E. N., 1948, The Mazon Creek eurypterid: A revision of the genus

Lepidoderma: Illinois State Mus., Sci. Papers, v. 3, p. 46 p., 8 pls.

——, 1950, A new Silurian *Hughmilleria* from West Virginia: Jour. Paleontology, v. 24, no. 2, p. 226–228, pl. 38.

——, 1950a, A new Silurian eurypterid from Florida: Jour. Paleontology, v. 24, no. 2, p. 229–231, pl. 38.

——, 1951, Downtonian (Silurian) Eurypterida from Perton, near Stoke Edith, Herefordshire: Geol. Mag., v. 88, p. 1–24, 3 pls.

——, 1954, Note on a new Silurian (Downtonian) scorpion from Shropshire, England: Jour. Paleontology, v. 28, no. 4, p. 485–486.

——, 1958, Some previously unknown morphological structures of *Carcinosoma newlini* (Claypole): Jour. Paleontology, v. 32, p. 295–303, pls. 41–43.

——, 1958a, The genera, species and subspecies of the Family Eurypteridae, Burmeister, 1845: Jour. Paleontology, v. 32, no. 6, p. 1107–1148, 6 pls.

—— & CASTER, K. E., 1955, The Pterygotidae of the Silurian Vernon shales of New York: Jour. Paleontology, v. 29, no. 6, p. 1041–1047.

LAURIE, M., 1899, On a Silurian scorpion and some additional eurypterid remains from the Pentland Hills: Trans., Royal Soc. Edinb., v. 34, p. 575–590, 4 pls.

MARSTON, A., 1870, On the transition beds between the Devonian and Silurian: Geol. Mag., v. 7, p. 408–410.

MURCHISON, R. I., 1839, The Silurian System, founded on Geological Researches, etc.

——, 1853, On some of the remains in the Bone-bed of the Upper Ludlow rock: Q.J.G.S., London, v. 9, p. 16–17.

NIESZKOWSKI, J., 1858, De Euryptero remipido: Dorpat.

——, 1859, Der Eurypterus remipes von der Insel Oesel: Arch. Naturgesch. Liv-, Esth-, und Kurlands, ser. 1, v. 20.

O'CONNELL, M., 1916, The habitat of the Eurypterida: Bull. Buffalo Soc. Nat. Sciences, v. 11, no. 3, 277 p.

POWRIE, J., 1864, On the fossiliferous rocks of Forfarshire and their contents: Q.J.G.S., London, v. 20, p. 413–429, 1 pl.

PŘANTL, F. & PŘIBYL, A., 1948, Revise Různorepych (Eurypterida) z Českého Siluru: Rozpravy Státního Geologického ústavu Československé Republiky, Svasek 10, 116 p., 6 pls.

PŘIBYL, A., 1952, In the genus *Adelophthalmus* Jordan & Meyer, 1854 (Eurypterida) and its representatives in the Upper Carboniferous of Czechoslovakia: Rozpravy 11. tridy České akademie, v. 53, no. 2, 17 p., 2 pls.

RUEDEMANN, R., 1919, A recurrent Pittsford (Salina) fauna: N. Y. State Mus., Bull. nos. 219–220, p. 205–222, pls. 1–3.

SARLE, C. J., 1903, A new eurypterid fauna from the base of the Salina of Western New York: N. Y. Museum, Bull. no. 69, p. 1080–1108, pls. 6–26.

SALTER, J. W., 1852, Description of the *Pterygotus problematicus* Agass.: Q.J.G.S., London, v. 8, p. 386–388, 1 pl.

——, 1855. see: Sedgwick & McCoy, 1855.

——, 1856, On some new Crustacea from the uppermost Silurian rocks: Q.J.G.S., London, v. 12, p. 26–34.

——, 1856a, *in* Murchison's Siluria, 2nd. ed.

——, 1859. see: Huxley & Salter, 1859.

——, 1859a, On some new species of *Eurypterus;* with notes on the distribution of species: Q.J.G.S., London, v. 15, p. 229–336.

——, 1859b, *in* Murchison's Siluria, 3rd. ed.

——, 1867, *in* Murchison's Siluria, 4th. ed.

——, 1868, Report Brit. Assoc., Trans., Norwich Meeting, p. 78.

——, 1873, Catalogue of Cambrian and Silurian fossils, Woodw. Mus., 4 to.

SCHLÜTER, C., 1881, Vorlage eines der Gruppe der Merostomen angehörigen Krebses aus dem rheinischen Unterdevon: Jber. niederrh. Ges. Bonn. Verh. naturh. Ver. Rheinld. Westf. 38, S. 210.

SEDGWICK, A. & MCCOY, F., 1855, British Palaeozoic rocks and fossils; with Appendix A, by J. W. Salter: Descriptions of a few species from Wales and Westmoreland referred to in the foregoing work: p. 175, p. V.

STØRMER, L., 1934, Merostomata from the Downtonian sandstone of Ringerike, Norway: Norske Videnskaps—Akad. i Oslo, I Matem.—Naturvid, Kl., 1933, no. 10, 125 p., 12 pls.

——, 1934a, Downtonian (Silurian) Merostomata from Spitsbergen, with remarks on the suborder Synzyshosura: *ibid.*, 1934, v. 2, no. 3, 26 p., 2 pls.

——, 1934b, A new eurypterid from the Saaremaa- (Oesel) beds in Estonia: Tartu Univ., Geol. Inst., Pub., p. 244–250, 1 pl.

——, 1934c, Eurypterid remains from the Ludlow zone 9d (Silurian) of Ringerike: Norsk Geol. Tidssk., v. 14, p. 119–126.

——, 1936, Eurypteriden aus dem rheinischen Unterdevon: Preuss. Geol. Landesanst., Abh. N. F., H. 175, 74 p., 12 pls.

——, 1951, A new Eurypterid from the Ordovician of Montgomeryshire, Wales: Geol. Mag., v. 88, p. 409–422.

——, 1955, Treatise on Paleontology, Part P, Arthropoda 2, Chelicerata with sections on Pycnogonida and Palaeoisopus, Eurypterida: p. P23–P41.

STRICKLAND, H. F., 1852, On a protruded mass of Upper Ludlow rock at Hagley Park, in Herefordshire: Q.J.G.S., v. 8, p. 381–385.

SYMONDS, W. S., 1855, On the geologic range of the *Pterygotus problematicus:* Edinb. New Philos. Jour., v. 1, n.s., p. 269–271.

——, 1956, Upper Ludlow bone-bed near Malvern: Edinb. New Philos. Jour., new ser., v. 3, no. 1, p. 172.

——, 1856a, On the Transition-Beds from the Upper Silurian into the Old Red Sandstone into the Carboniferous rocks in Herefordshire: Edinb. New Philos. Jour., v. 4, n.s., p. 239–243.

——, 1872, Notes on Silurian localities in the west of England where fossil Crustacea belong-

ing to the order Merostomata have been discovered. *In* Woodward, H., 1866–78, A Monograph of the British Fossil Crustacea, etc., Paleontogr. Soc., London, p. 92–104.

VĂSCĂUTANU, T., 1932, Formatiunile Siluriene din Malùl Românesc al Nistrului (Contribuţiuni al Cunoasterea Paleozoicului din Moldopodolic). An. Inst. geol. României, xv, v. 15, p. 425–663, 12 pls.

WOODWARD, H., 1864, On a nearly perfect specimen of *Eurypterus lanceolatus* (Salter) from the Upper Ludlow rock at Lesmahagow, Lanarkshire: Geol. Mag., v. 1, p. 107–114, pl. V.

——, 1868, On some new species of Crustacea from the Upper Silurian rocks of Lanarkshire, etc.; and further observations on the structure of *Pterygotus:* Q.J.G.S., London, v. 24, p. 289–296, 2 pls.

——, 1866–1878, A monograph of the British Fossil Crustacea belonging to the order Merostomata: Palaeontogr. Soc., Mem., 263 p., 36 pls.

——, 1871, On a new species of *Eurypterus* (*E. Brodiei*), from Perton, near Stoke Edith, Herefordshire: Q.J.G.S., London, v. 27, p. 261–263.

——, 1871a, Trans., Woolhope Field Naturalists' Club.

——, 1877, Catalogue of the British Fossil Crustacea with their synonyms and the range in time of each genus and order: British Mus., N. H., p. 64–69.

——, 1887, On a new species of *Eurypterus* from the Lower Carboniferous shales of Glencartholm, Eskdale, Scotland; Geol. Mag., n.s., v. 4, p. 481–484, pl. 13.

——, 1907, Two new *Eurypterus* from the Coal Measure of Ilkeston, Derbyshire: Geol. Mag., n.s., v. 4, p. 277–282, pl. 13.

——, 1909. Note on the genus *Hastimima* from Brazil and the Cape: Geol. Mag., dec. 5, v. 4, no. 11, p. 486–488.

JOURNAL OF PALEONTOLOGY, V. 35, NO. 4, P. 836–865, PLS. 97–98, 6 TEXT-FIGS., JULY, 1961

PALEOLIMNOLOGY: PART 2—HARVEY AND SEDGWICK COUNTIES, KANSAS: STRATIGRAPHY AND BIOTA

PAUL TASCH
University of Wichita, Kansas

ABSTRACT—Several outcrop belts of Wellington conchostracan-bearing beds were discovered in Harvey and Sedgwick Counties, Kansas. Data of the present study indicate that these belts are restricted, relatively narrow, and discontinuous. In turn, this reflects the distribution and characteristics of the Leonardian ponds represented. These were small (in some cases puddle size), areally non-persistent, and very shallow.

A conchostracan-bearing horizon, the C_1 horizon, was found to be traceable throughout the two-county area. At a critical exposure, (Annelly 1A), it was found to be $11\pm$ feet above the Annelly gypsum. At this same exposure, but nowhere else in the two-county area, two younger clam-shrimp horizons were found. Once the interval above the Annelly of the C_1 horizon was established, it was possible to locate clam-shrimp beds at predicted localities.

The biota associated with fossil clam-shrimp include: vertebrate remains (lizard scales, plates, teeth), arthropods (insects, ostracods, xiphosurans), mollusks (pelecypods, gastropods), plant remains (seeds, leaves, carbonized and silicified wood, charophytes, spores). The following new forms are figured and described: xiphosurans—*Pringlia leonardensis*, n. sp., *Strongylocephalus charactis*, n. gen., n. sp., *Hypatocephala rugosa*, n. gen., n. sp., *Bifarius comptae*, n. gen., n. sp.; mollusks—(gastropods) *Patelloidea limnensis*, n. gen., n. sp., *Permoplanorboidea primus*, n. gen., n. sp., *Rugoplanorboidella sedgwickii*, n. gen., n. sp., *Wellingtonia producta*, n. gen., n. sp.; (pelecypods) *Stagnestesta solitaria*, n. gen., n. sp., *Rostrotortus dissimilis*, n. gen., n. sp., *Productae dunbaris*, n. gen., n. sp., *Elliptoidea vulgaris*, n. gen., n. sp.

Variable salinity in, and differential evaporation of, contemporaneous Leonardian ponds can account for the observed sporadic occurrence of hopper crystals and cubic salt casts in clam-shrimp beds.

A method for deriving maximum clam-shrimp occupancy (in years) in different contemporaneous Leonardian ponds is outlined. Three different types of events are postulated to account for the observed distribution of the fresh water and/or brackish water mollusks: speciation in small pond situations, connections of discontinuous ponds by temporary drainage, and marine invasion.

ACKNOWLEDGMENTS

THE research reported here was supported by NSF G-4150. Field work in Dickinson and Marion Counties was also completed under this grant and will be reported on separately. The project has been extended under NSF G-7320 and carried to Sumner, Harper, and Reno Counties, Kansas, and Kay County, Oklahoma. Further work in Kay and Noble Counties, Oklahoma, is projected.

Specific mention should be made of the intelligent, enthusiastic, and conscientious field and laboratory assistance given by Bernard Shaffer. Photography was done by Bob Mallory.

SOME QUESTIONS RAISED

Following the pilot study of the Jester Creek Section (Tasch, 1958), a series of questions was formulated: Can the clam-shrimp horizon be traced? What is the best procedure to follow in search of such outcrops as the Jester Creek exposure? Is the horizon found at Jester Creek the oldest conchostracan bed in the Wellington? How extensive are conchostracan-bearing beds of Leonardian age and how are they distributed? What is their areal extent? What is the composition of the associated flora and fauna? What is the evidence of speciation among clam-shrimps during this period of time?

OUTCROP BELT A

It was found that the most likely places to look for clam-shrimp-bearing beds was along the Jester Creek drainage system. This was determined by a general survey of the area. Subsequently, nine additional out-

crops were found. An eleventh outcrop was located by exploration of the area between the pilot section and the town of Annelly where the type section of the Annelly gypsum is exposed. These eleven outcrops occurred in a belt some eight miles long and about one-half mile wide. The entire area surrounding this belt was carefully explored and no additional clam-shrimp-bearing exposures were found. This outcrop belt will be referred to as Belt A hereafter. The location of Belt A is shown on Text-fig. 1.

Section 10 in Belt A was found to be completely barren of fossils. The insoluble residues and microscopic examination of samples confirmed the field observation that all beds in this section were unfossiliferous. Yet, the lithologic similarities to the clam-shrimp-bearing sections were unmistakable. It was found that this barren section could be related to the other sections in this belt by an evaporitic shale found here and in section 11, somewhat less than two miles to the southwest. The latter section bore the lowermost clam-shrimp bed (hereafter referred to as C_1).

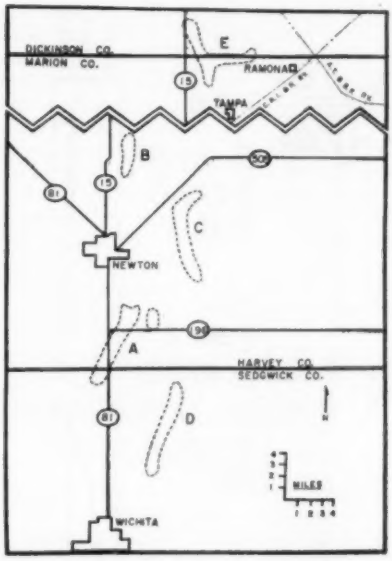
OUTCROP BELTS B AND C

A few outcrops (Belt C) were found on and near the Harvey-Marion County line. The clam-shrimp bed was found to contain insect fossils. Since the first section studied in Belt A (Tasch, 1958) showed insect molts in the insoluble residues, this became an important clue. Subsequently, insect wings were found on the same slab with clam-shrimps at this locality. Text-fig. 1 shows these outcrops as well as those in Belt C.

After Belt A was traced, it was decided to explore the area north of Annelly. This led to the discovery of several very critical exposures. One of these, being the key to the answers to several questions raised earlier, is discussed separately below.

ANNELLY 1A EXPOSURE

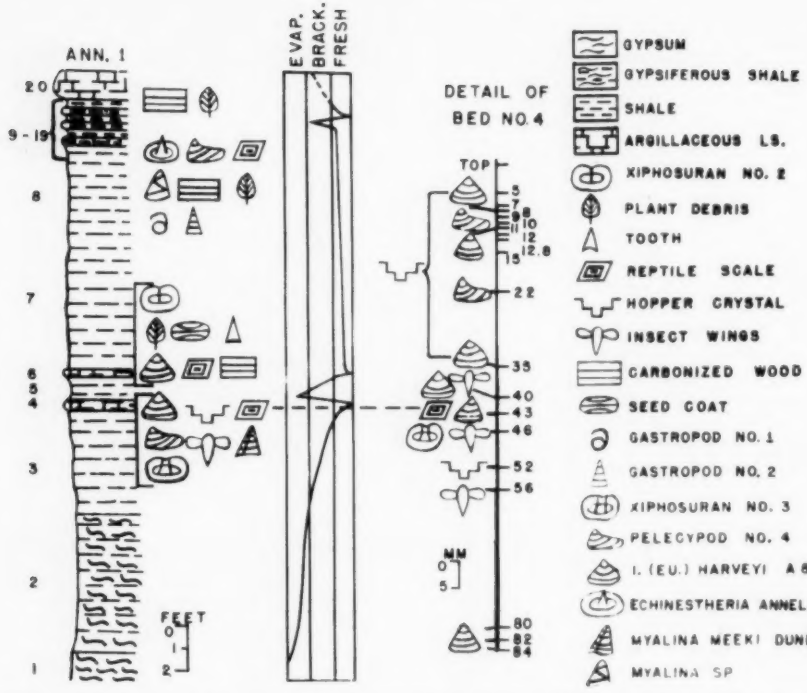
It was found that the Annelly gypsum cropped out here (Annelly 1A) and was overlain by gypsiferous shale and argillaceous shale. The next overlying bed was the C_1 horizon described earlier. It was found to be 10.4 feet at this place and an estimated 11 ± feet above the top of the Annelly gypsum in



TEXT-FIG. 1—Kansas outcrop belts of Leonardian clam-shrimp-bearing beds. Belt D—Sedgwick County; Belts A and C, southern portion of B—Harvey County; northern portion of B and southern portion of E—Marion County; northern portion of E—Dickinson County. *Note:* Belt D does not show locality Sedgwick II. Since fossil clam-shrimps have recently been found in the city of Wichita, Belt D now extends to this new outcrop.

Harvey County. That finding answered another question too. The C_1 horizon was the oldest of the middle Wellington conchostracan-bearing beds found in this area (Text-fig. 2).

Preliminary study of samples from Annelly 1A indicated a second clam-shrimp horizon. Subsequent work on samples showed that in all there were at least three stratigraphically distinct clam-shrimp horizons. The lowermost C_1 horizon (bearing clam-shrimps and insects) was overlain by 1.10 feet of shale and above that a C_2 clam-shrimp horizon occurred. This C_2 horizon was separated from the uppermost C_3 horizon by almost ten feet of shale. It was on the C_3 horizon that the clam-shrimp *Echinestheria* was originally found. Since then, it has been found in the lower horizon (C_1) also as at Sedgwick I. (The taxonomy of



TEXT-FIG. 2—Locality Annelly I-A. Columnar section showing lithology, thickness of beds, fossil fauna and exact stratigraphic position relative to the top of the Annelly gypsum of the three conchostracan-bearing horizons. The middle column depicts in log form the alternation of three environments: Evaporative (Evap.), Brackish, and Fresh Water. The bases for this interpretation are respectively, evaporites, the brackish water mollusk *Myalina meeki* Dunbar, and fresh water clam-shrimps and associated flora and fauna. The detail of Bed No. 4 shows the vertical distance in millimeters below the top of the bed of the respective fossil biota. The bracketed portion (to the left of the vertical) shows that hopper crystals were found from 5 to 35 mm. below the top of the bed as well as 52 mm. below the top.

conchostracans of the *Echinestheria* type is under study and some revisions are indicated.)

The C_1 horizon at this locality was also found to bear insect fossils and thus correlation with the outcrops of Belts B and A became possible.

Now one could locate new outcrops by studying a map of plotted localities. These data were taken in conjunction with the known interval separating the C_1 horizon from the top of the Annelly gypsum and the probable interval at any given place in Harvey and Sedgwick Counties. In this way seven additional outcrops were found at, or very near to, predicted localities (Belt C, outcrops IV–VII; Belt B, Harvey I; and Belt D, Sedgwick I, II, and IIIB). It was also possible to determine in the field, based on the same rationale, that in the city of Wichita, at the proper interval above the Annelly gypsum, the C_1 horizon was barren of conchostracans. A recent find (Sedgwick II) indicates that clam-shrimps do occur at one locality in the city. It should be noted that the Annelly gypsum is exposed in several areas in the city of Wichita.

The C_1 horizon in Sedgwick County

(Belt D) was found to contain conchostracans and insect wings. It thus became possible to correlate this horizon with its equivalents that bear conchostracans and insects in Belts A, B, and C in Harvey County. In this manner, *all* isolated outcrops in the two counties reported on here have been correlated. Subsequent work extended this correlation to Marion and Dickinson Counties and will be reported on in a later paper of this series. It should be noted that in Sedgwick and Harvey Counties, only at locality Annelly 1A was more than one conchostracan horizon found.

AREAL EXTENT OF LEONARDIAN PONDS

The entire study of the Permian clam-shrimp beds of Kansas was motivated by the writer's curiosity about the areal extent of such fresh-water bodies. Information was available for living forms. For example, Pennak (1953) noted that clam-shrimps are generally absent in fresh-water bodies greater than one acre in extent. Other reports (Kelley, 1956) supplemented by the writer's own collections of living forms and those of a coworker, J. R. Zimmerman, indicate that any water-filled depression in a field, flood plain, or dried out stream bed, or in a road dip or ditch, *however limited in extent*, can and often does, permit clam-shrimp fry to hatch from eggs that had been previously dispersed by wind over a given area.

The situation that prevailed in a given geologic past (in this case Leonardian time) has not heretofore been examined. Data of the present study make clear that the several newly discovered clam-shrimp outcrop belts are very restricted, relatively narrow, and discontinuous. The ponds that are reflected in the conchostracan-bearing beds of such belts were likewise very small, areally non-persistent, and also very shallow. But, whereas a given pond was areally very limited, many such ponds scattered over larger areas are what constitute the present outcrop belts. The reason that the newly discovered beds were bypassed by the many workers who have gone over this area previously is simply lack of recognition of the important finding that while individual ponds were small and very limited, many such contemporaneous ponds, even though discontinuous, were spread over large areas.

Furthermore, it has been found that in small horizontal distances (measured in tenths of a mile or within a mile) between certain outcrops (Annelly IA, Annelly ID, Annelly IIIA, Annelly IV), the shale interval separating the C_1 from the C_2 horizon or the C_2 from the C_3 horizon, thickens or thins. Among probable explanations, a plausible one could be that the variable thickness of the shale interval corresponds to deepening of shallow ponds toward the center and thinning on the margins. Photographic evidence of wedging-out conchostracan beds will be published in a later paper dealing with sedimentary aspects. Such evidence places the conclusion beyond conjecture that individual Wellington ponds were very restricted in areal extent.

HOPPER CRYSTALS, ETC.

In studying the sections that follow below, it is useful to note, in addition to the conchostracans and related fauna on any given horizon, occurrences of hopper crystals. These were found in Belt A at locality Jester Creek II, Belt C, localities Annelly ID, Annelly IA, and Annelly IIIA. All were on the C_1 horizon associated with the lowermost clam-shrimp-bearing bed.

Such crystals form generally under evaporating conditions (Dellwig, 1953). A series of experiments were carried out by the writer and his assistant to determine if hopper crystals could be made in the laboratory. Saturated solutions of Carey Mine salt were prepared. At first, concentrated HCl, and in other experiments concentrated H_2SO_4, was added rapidly. In each case microscopic hopper crystals could be observed forming in the Petri dish. The reaction was exothermal with an increase in temperature from the initial 19.5°C or 20.5°C to 26.0°C and 27.5°C respectively, when concentrated HCl was added. Concentrated HNO_3, HF, H_2O_2 all gave negative results.

Briggs (personal communication, March 26, 1959) notes that some hopper crystals he has seen do not suggest formation under evaporating conditions. The above-mentioned experiments indicate that concentrated acids will elevate the temperature. Thus, they may effectively simulate internally, the external evaporative condi-

tions arising from elevated temperatures. Yet, there is little doubt that the Wellington hopper crystals collected during the course of this field study indicate evaporative conditions. This can be supported by such additional data as mudcracks, salt casts, and the faunal association at locality Annelly IA, for example. K. E. Caster (oral communication) indicated that he had observed, on coastal salt flats of Brazil, clam-shrimps and xiphosurans. These occur together as fossils in the Annelly IA section in a bed that also contains hopper crystals.

At the time of the existence of the ponds of the portion of Leonardian time being studied, aridic conditions must have prevailed. Such ponds formed by shrinkage of larger bodies of water.

However, C_1-time aridity was neither as extensive nor as long-lived as the aridity of the older Annelly gypsum time. In fact, estimates of the total time represented by the C_1 clam-shrimp beds (Text-fig. 3) indicate periods lasting from one season to as much as 150 years. The non-persistence of hopper crystals in the area and horizon studied (or, more accurately, their sporadic occurrence) shows that some ponds were drying up while others still retained a cover of water. There is also evidence derived in other counties of Kansas and Oklahoma that many such ponds had relatively negligible salinity while others nearby had adequate salinity to give rise to either small cubic or pyramidal salt crystals. This accounts for the sporadic distribution of both salt casts and hopper crystal casts.

TIME VALUES FOR CONCHOSTRACAN OCCUPANCY OF LEONARDIAN PONDS

The pilot study (Tasch, 1958) brought to light the fact that a time value calculation in years was possible based on study of the fossil evidence. By a series of simple steps outlined in Text-fig. 3, it was found possible to evaluate the number of years of intermittent occupancy by Leonardian clam-shrimps of respective ponds now represented by a given fossiliferous bed at a given locality. It should be made unmistakably clear that any errors hidden in the chain of

TELLING TIME BY CLAM SHRIMPS

(A)
GEN II — (B)
0.003"/YR=S
GEN I — (A)
DETERMINE ANNUAL RATE OF SEDIMENTATION (S) BETWEEN ANY TWO SEPARATED CLAM SHRIMP SURFACES "A" AND "B"
S = F/G

(B)
SP I SP II SP III
(B) (A)
EACH DISTINCT SPECIES OR SUBSPECIES OF CLAM SHRIMP = ONE SEASON (OR YEAR)
EX: 3 SPECIES OR SUBSPECIES = 3 YEARS OR GEN = G

(C)
R
R = TOTAL THICKNESS OF CLAM SHRIMP BEARING BEDS
T = R/S

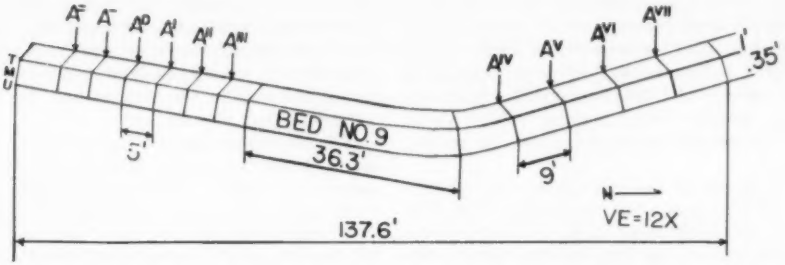
(D) MEASURED QUANTITIES
R = TOTAL THICKNESS
F = SMALLEST THICKNESS BETWEEN ANY TWO CLAM SHRIMP BEARING SURFACES
G = LARGEST NO. OF DISTINCT GENERATIONS ON ANY SURFACE
CALCULATED QUANTITES
G' = HIGHEST NO. OF CLAM SHRIMP GENERATIONS POSSIBLE (G' = R/F)
S = ANNUAL RATE OF SEDIMENTATION
T = TIME IN YEARS

TIME-VALUES FOR MAXIMUM DURATION OF CONCHOSTRACAN OCCUPANCY IN SELECTED LEONARDIAN PONDS IN HARVEY & SEDGWICK COUNTIES, KANSAS

LOCALITY	NUMBER OF CONCH. GEN. (G)	TOTAL THICKNESS OF CONCH. BED (R) (FT.)	TIME VALUE (YRS.) T = R/S*
J CRK. 2	9	0.12	40.0
" " 6	7	0.24	80.0
ANN 1A	11	0.28	93.3
J CRK. 1	18	0.32	106.6
" " 4	10	0.39	130.0
" " 3	9	0.45	150.0

*S = .003"/YR.

TEXT-FIG. 3—A Crustacean clock. Upper panel: Methodology, measured and calculated quantities. Lower panel: Table of calculated time values in years for specific localities and horizons.



TEXT-FIG. 4—Method of sampling. Locality Jester Creek II, Bed No. 9. T = top, M = middle, U = upper portion of Bed No. 9. The middle unit, 36.3 feet long, is slumped and covered. Width of the ledge exposed by channelling, 1.0 feet; thickness, 0.35 feet. Horizontal distance between successive samples (letter "A" and respective superscripts), southern end of outcrop, 5.0 feet; northern end, 9.0 feet. This method permits very precise location of faunal and lithologic elements. For example, at A^O, on the top surface, a cast of a hopper crystal was collected; at A^V, on the undersurface, the new gastropod genus and species, *Patelloidea limnensis* was collected. At this last-named collecting substation, no fossils occurred on top, middle, or undersurface, other than the new gastropod. At A^I, on the middle surface, the greatest density of fossil clam shrimps occurred. By using this method something of the original distribution and density of the biotic elements in a given Leonardian pond may be approximated.

reasoning leading to the calculations given in Text-fig. 3, are unlikely to be of a magnitude greater than ten or some simple multiple of ten. However, when one takes into account that we are treating a seasonal animal whose life cycle is fairly well established, the results appear quite plausible.

The example at locality Marion IIIA can be cited. Here the total thickness of the conchostracan-bearing bed is 0.95 feet. However, most careful study of this bed revealed that conchostracan valves occurred only on a single plane, namely, the undersurface. In this case one can state, with a high degree of accuracy, that a single season (year) is represented. If there had been viable progeny from this generation in this given pond, they would have appeared as fossilized valves at some height (in millimeters) above the base of the bed.

If we follow Kelley (Tasch, 1958, p. 60) then we may take as a value, two to three days between each molt of a clam-shrimp. Successive molts being represented by growth lines, it is thus possible also to determine the lifespan of individual clam-shrimps now found as fossils. Even if this total varied from one species or genus to another, again the proper order of magnitude would be ascertained.

The value of calculating maximum duration of clam-shrimp occupancy in different Leonardian ponds is largely a comparative one. That is, from these data it becomes clear that contemporaneous Leonardian ponds endured as ponds for variable lengths of time. That is to say, they did not dry up all at once, although evidence of shrinkage is abundant. It also follows that clam-shrimp occupancy of such ponds some 200 million years ago was differentially intermittent from one pond to another. (Cf. number of generations and total thickness at localities Jester Creek. I and Jester Creek III. Twice as many conchostracan generations occurred at the former and yet it endured a shorter period of time than the Jester Creek III pond). The lesser number of generations found in some beds of greater thickness indicates clearly that such ponds were barren of clam-shrimps season after season.

As far as the writer has been able to determine from a search of the literature, these observations importantly supplement limnological data on living clam-shrimp populations. To illustrate this point for living clam-shrimps: At a particular pond in 1958 the writer collected abundant clam-shrimps, more than one-half being females bearing eggs. At the same pond sampled daily by an assistant from June 1, 1959 to July 29, 1959, no clam-shrimps have been found. In the rock record this would be rep-

resented by a plane bearing the 1958 clam-shrimp valves overlain by the increment of sediment from the summer of 1958 to that of 1959. If later in the 1959 season or during the summer of 1960 clam-shrimps again appear, another plane bearing valves would be represented in some future rock record, etc.

It should be noted that it is not always possible to determine the number of generations since, for fossil clam-shrimps, this depends on how the rock bearing such fossils weathers out or how the fossils can be removed from the outcrop. However, a sufficient number of cases are now at hand spread through several counties where slabs were found that could be parted on conchostracan-bearing planes. It is such evidence from which the year calculations given in Text-fig. 3 were made.

THE MOLLUSCAN FAUNA

The sparsity of information on nonmarine Mollusca of the North American Permian can readily be determined by study of bibliographic indices of the past decade. Henderson (1935 p. 23) observed: "I have found only one species of nonmarine mollusk attributed to the Permian of North America; namely, *Anthracopupa dundardana* Stauffer and Shroyer, Dunkard Permian, near Pleasant Grove, Belmont County, Ohio. *Doubtless many other species existed on the continent during Permian time.*" (Italics mine.) Some of these other species uncovered during the research reported here are figured on Plate 97.

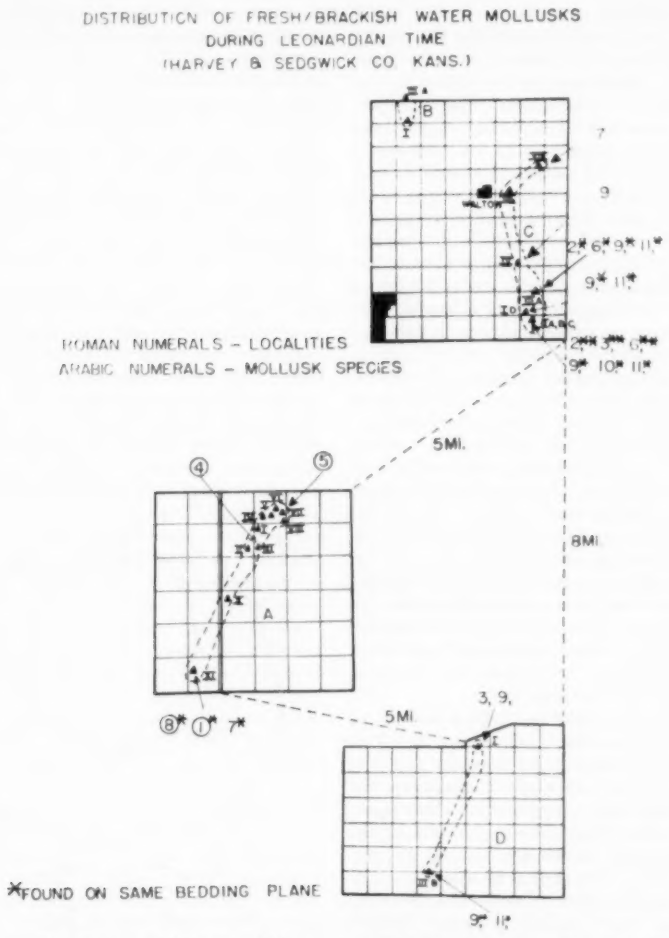
Certain general observations regarding Leonardian mollusks are indicated after study of the material at hand. First, the state of preservation is poor. Second, the mollusks were small-to-minute in size. Third, with the exception of the species shown on Pl. 97, fig. 9, molluscan populations were sparsely represented (Text-fig. 5).

It should be noted that at all the localities where the different mollusks were found, the conchostracans were chiefly of the same species. The localities referred to occurred in Harvey and Sedgwick Counties. This raises the question as to why such uniformity occurred in clam-shrimp distribution in contrast to the observed variation in molluscan species. The simple explanation is that clam-shrimp eggs are dispersed by wind every season or whenever ponds or creek pools dry up, whereas molluscan eggs cannot withstand desiccation and cannot be dispersed in that manner.

The molluscan species found can be accounted for by three different types of events: (1) Species restricted to a single outcrop and bed indicate speciation in isolated pond situations (Pl. 97, figs. 1,4,5 and 8); (2) species found in more than one outcrop belt but not in all indicate a connection by either a continuous body of water or overflow of ponds and connections between discontinuous ponds by temporary drainage. If the former, then subsequent drying would leave isolated ponds containing the same molluscan species (Pl. 97, figs. 3,7); (3) species like *Myalina meeki* that Dunbar attributed to brackish water (Pl. 97, fig. 6) and others like that illustrated on Plate 97, figure 9 which is the most widely distributed species found and occurs in assemblages of the coquina type, and the species shown on Plate 97, figure 11 are likewise probably of brackish origin. These forms would indicate that the sea invaded a coastal swamp area in which the isolated ponds mentioned earlier were located. It will be noted that species of the third type (brackish water forms) occur with fresh water types.

Coquina-like assemblages of snails or clams are not uncommon in small freshwater pond or stream pool situations. One such pool in a drying stream bed was sampled by J. R. Zimmerman and Bob Mallory. This was done in conjunction with a study of the contemporaneous limnology in and around the Leonardian outcrop belts reported here. Approximately seventy clams occurred in an area 100 mm. square. In another pond, a coquina-like assemblage, at least six feet long and containing hundreds of snails, was observed.

The writer and the above-named project participants have independently observed high- and low-spired gastropods (four or five distinct species) in ponds that bear clam-shrimps at some seasons. In drying stream pools, observed during August, 1959 in Harvey County, clam-shrimps, snails, and clams have been found together. Thus, the Leonardian situation has modern paral-



TEXT-FIG. 5—Distribution of fresh/brackish water mollusks during Leonardian time (Harvey and Sedgwick counties, Kansas). Arabic numerals designating mollusk species at a given locality refer to figure numbers on Plate 97. Thus, Number 7 refers to *Rostrotortus dissimilis*, figured on Plate 97. Cf. Text-figure 1, for relationship of the outcrop belts shown.

lels in the same general region. This last thesis is documented and discussed elsewhere.

XIPHOSURA SHIELD PARTS AND CERTAIN RESEMBLANCES IN BLATTARIA PRONOTA

Four xiphosurans are described in this paper (Pl. 98). J. R. Zimmerman, who is doing the insect systematics for this project, suggested that certain of the xiphosurans bore resemblances to Tillyard's figures of Blattaria pronota (Tillyard, 1937, text-figs. 1,14,17,23,24,28). This led the writer to several different lines of investigation in order to establish the basis for, or the actual existence of, this resemblance. The results are briefly reviewed below.

Three modern members of the order Blattaria (cockroaches) from the University of Wichita Insect Collections were examined (under the microscope) by the writer and independently by Zimmerman. The forms examined included *Periplaneta americana* Linn., *Blatella germanica* Linn., and *Blatta orientalis* Linn. In each case a smooth pronotum markedly convex upward was seen. The reverse side, bearing head and appendages, was removed to lay bare the rachis. Tillyard (1937, p. 173) defines the rachis: "In fossilized pronota the central convex portion, indicating the limits of the pronotum proper, as distinct from its expansion, is termed the *rachis*."

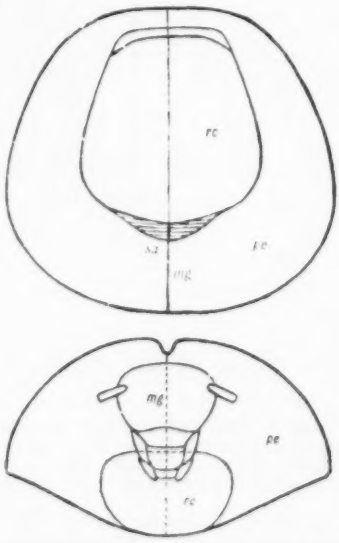
In the modern forms examined, the rachis does not elevate from the reverse surface of the pronotum as a bulbous or smoothly convex expansion. Rather, it is a finely chitinous film that bears numerous depressions. If pressed in bottom muds or infiltrated by muds as a single unit with the pronotum, the central expansion could not result in a smooth convexity. Curiously, only one of Tillyard's figures (text-fig. 24) shows markings on the fossilized rachis. Elsewhere (p. 194) he notes "three or possibly four pairs of slight, oblique swellings placed on either side and running from near the margins backwards and inwards."

The ornamentation in modern pronota as revealed by binocular microscope study is expressed as a random pattern of wavy lines not on the surface itself but within the chitin. These lines stand out as white under reflected light. They do not persist over the entire pronotal expansion which is pigmented and amber-brown in color.

One of the important features of Blattaria pronota is the median groove. Tillyard (p. 172) observed that in many Paleozoic larval forms the pronotal expansion consisted of two lobes, i.e., separate lobes, one on each side of the prothorax. While in the adult, "the median groove marks the line of later fusion of these two lobes." In the modern species of Blattaria studied, the median groove is a faintly expressed line seen under reflected light. The specimens had to be oriented to permit the light to fall on them at a certain angle in order to catch sight of it at all. The median groove does not provide any topographic expression on the obverse or reverse sides of the pronotal expansion.

These three features and some others to be discussed later bear directly on certain resemblances of the xiphosuran species described here and two of the pronota (one fossil) figured and described by Tillyard. *Hypatocephala rugosa* (Pl. 98, fig. 3) bears a superficial resemblance to *Permoblattina curta* (Tillyard, text-fig. 14). This resemblance extends to comparable size and shape and certain other features. Regarding ovate configuration of both, it should be noted that in xiphosurans (*Liomesaspis*, for example, Størmer, 1955, text-fig. 13.10) such shape is not unknown.

The differences between the shield of *Hypatocephala* and the pronotum of *Permoblattina curta* (Text fig. 6A) are notable. The xiphosuran bears no median groove that runs from anterior to posterior on the prono-



TEXT-FIG. 6—Blattaria pronota figured by Tillyard. (upper) Pronotum of *Permoblattina curta* (Sellards), Yale Coll. Spec. No. 15676; (lower) prothorax of *Oniscosoma granicollis* Saussure (Recent, Australia), ventral view. mg = median groove, pe = pronotal expansion, rc = rachis, sa = dorsal striated area.

tum. It bears sculpture on the cardiac lobe that might be taken as resembling a *rachis* of a cockroach pronotum but that could not correspond to sculpture caused by flattening a roach *rachis*. It bears posterior to the cardiac lobe a distinct elevated protruding ring. This superficially corresponds to the faintly expressed dorsal striated area in a similar posterior position relative to the Blattaria rachis. It also bears a feature not to be found on roach pronota, namely ophthalmic ridges reminiscent of the palpebral lobes of a trilobite.

The second xiphosuran described here, *Bifarius comptae* (Pl. 98, figs. 1A-B), may be compared to the prothorax of a Recent species of cockroach from Australia (Text-fig. 6B). Superficially, these two shields appear to be close in several characteristics. For example, in the Recent form, *Oniscosoma*, there is an anterior notch, and from the base of this notch the median groove extends across to the posterior margin. In *Bifarius*, a less pronounced incurvature anteriorly also has a "narrow line-like elevation" that proceeds from its base to the middle of the cardiac lobe. It has already been noted that the median groove in Blattaria pronota has no topographic expression on the shield. This contrasts with the characteristic feature of the xiphosuran subclass Limulina, in which the cardiac lobe is "commonly keeled" (Størmer, 1935, p. 18). *Bifarius* shows a keel and not a median groove.

Other distinctive features of *Bifarius* are: an ophthalmic ridge that conforms to the configuration of the cardiac lobe and expands posteriorly to right and left where it cuts the prosomal posterior margin and the ornamentation of the shield consisting of a succession of subdued radial rays that have surface expression. Neither of these features is to be found even by resemblance in Blattaria pronota.

Another point of interest concerns Sellards' original description of *Permoblattina permiana* (1908:512). This form was not figured by Sellards. Tillyard (1937, p. 194–201) figured the wings but he too failed to publish the evidence of "the larger pronotum of *P. permiana* (Sellards) attached to the insect itself in specimen 15678 a-b . . . " (p. 194). This is important because his line drawings (no photographs are given) of fossil Blattaria pronota are quite misleading when one consults the equivalent feature in modern forms. It is of even more importance that the unfigured pronota referred to above is the only one attached to the insect itself. All the pronota Tillyard figured are isolated body parts.

The puzzle is even more confounded when one turns to Sellards and learns that he did not even mention a pronota in his original description of the above-named species. That he was fully cognizant of the pronota is evidenced by his figures of crushed and broken pronota attached to the insect or as isolated body parts. Sellards' simple depictions of Blattaria pronota come closer to the reality of what they actually look like in modern forms than the more detailed yet misleading depictions of Tillyard. Tillyard referred his isolated pronota to the unfigured flattened specimen attached to the insect in the above-named specimen.

The preceding discussion raises the question as to whether some of the Blattaria pronota found as isolated body parts in a Permian insect collection, might not be xiphosurans? I have in mind the following pronota: Yale Univ. Coll. Spec. Nos. 15697, 15683 and cockroach *incertae sedis*, 15698. Any of these might belong to the Xiphosura, although study of type material and photographic evidence alone could resolve the matter. I should mention that mere occurrence of the so-called pronota with insects in itself is no evidence of their insect affiliation. The writer has collected Permian insects, xiphosurans, and other fossils, such as clams and clam-shrimps from the same horizon. Pertinent to this observation, *Hypatocephala* and *Bifarius*, the two xiphosurans superficially bearing resemblance to Blattaria pronota, were found in beds bearing no insects.

On the other hand, a xiphosuran bearing no resemblance to Blattaria pronota, namely *Strongylocephalus*, was found in an insect bed.

In light of the above analysis and discussion, it is concluded that *Hypatocephala* and *Bifarius* are properly assignable to the Xiphosura. It is hoped that this discussion

will at least alert paleontologists to the resemblances involved.

THE CONCHOSTRACAN FAUNA AND ASSOCIATED FORMS

Only new material not previously figured or reported is described in this Part and subsequent parts in preparation (cf. Tasch, 1958). Exclusive of the eight-to-nine orders of insects which are being studied by Zimmerman and will be described elsewhere, the biota consists of numerous plant fossils already covered by many authors (Sellards, 1909; Dunbar, 1924). Carbonized wood framents from locality Annelly I were found to consist of gymnosperm tracheid cells of the same type found by the author in carbonized wood interbedded with salt in the Carey salt mine (Tasch, 1960).

The new material consists of a charophyte species (*Aclistochara* sp.), three new xiphosuran genera, and one new species of the known xiphosuran *Pringlia*, a completely unknown fresh and brackish water molluscan fauna, with the exception of *Myalina meeki* Dunbar, consisting of four new genera of gastropods and four of pelecypods, with one genus and species undetermined in each group. In addition to the new conchostracan species to be described in Part 3, numerous incompletely identified objects are included in the material at hand, consisting of plant material, poorly preserved ostracod valves, abundant reptilian parts (scales, plates, jaw bearing conical teeth etc.) The xiphosuran and molluscan fauna is covered in this Part (2) whereas the rest of the fossils from Harvey and Sedgwick Counties will be covered in Part 3.

One of the questions raised by the author at the start of this project concerned the biota associated with the fossil clam-shrimps, about which almost nothing was known. This paper and subsequent parts will make clear that we can no longer speak of estheriid-bearing beds without taking cognizance of the macro- and micro-floral and faunal associates. This approach permits detailed reconstruction of the limnological situation precisely as it existed during Leonardian time.

EXPLANATION OF PLATE 97

FIG. *1*—*Permoplanorboidea primus* Tasch, n. gen., n. sp. Internal mold of dextral shell. Holotype: W.U. 301, ×20.

2—Gastropod genus and species undetermined No. 1. Sinistral, high-spired gastropod. W.U. 303, ×6.

3—*Rugoplanorboidella sedgwickii* Tasch, n. gen., n. sp. Internal mold of sinistral shell. Holotype: W.U. 302, ×34.

4—*Patelloidea limnensis* Tasch, n. gen., n. sp. (a) Apical view of patelliform shell; (b) side view showing apex overhanging anterior end. Holotype: W.U. 300, ×8.

5—*Stagnestesta solitaria* Tasch, n. gen., n. sp. Internal mold of left valve; note steepness of anterior side. Holotype: W.U. 304, ×6.

6—*Myalina meeki* Dunbar, 1924. W.U. 305, ×9.

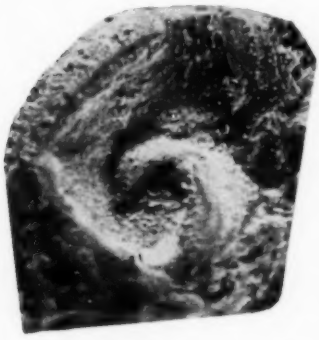
7—*Rostrotortus dissimilis* Tasch, n. gen., n. sp. Internal mold of right valve; note loop on beak. Holotype: W.U. 306, ×11.

8—Pelecypod genus and species undetermined No. 1. Internal mold of left valve. W.U. 307, ×6.

9—*Productae dunbaris* Tasch, n. gen., n. sp. Lateral view of left valve and covered portion of right valve above. Holotype: W.U. 308, ×9.

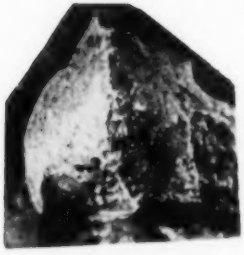
10—*Elliptoidea vulgaris* Tasch, n. gen., n. sp. Left valve. Holotype: W.U. 309, ×5.

11—*Wellingtonia producta* Tasch, n. gen., n. sp. Dextral, high-spired gastropod. Holotype: W.U. 310, ×4.

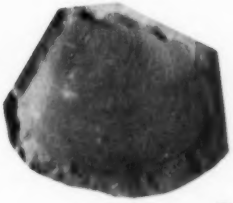


1

3

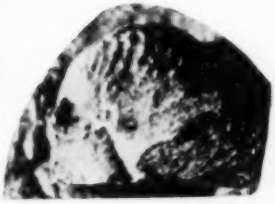


4A

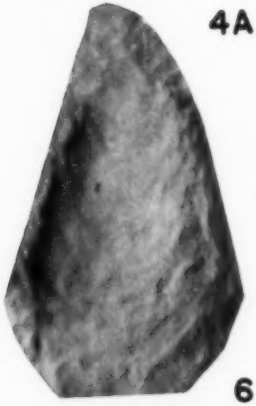


5

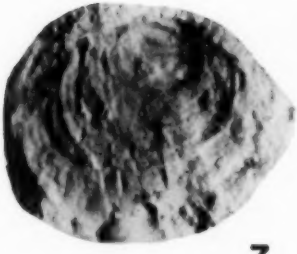
2



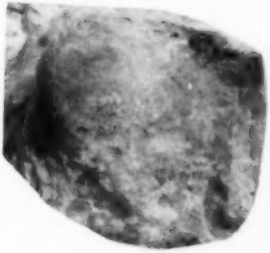
4B



6



7

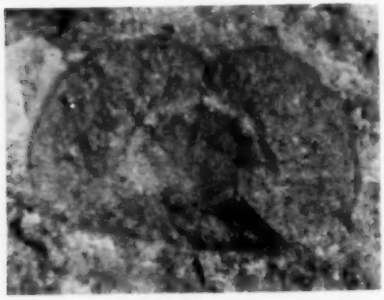


8

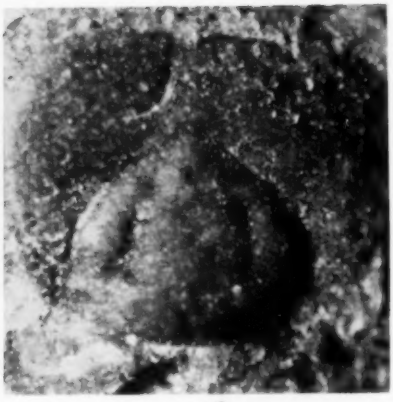
9

10

11

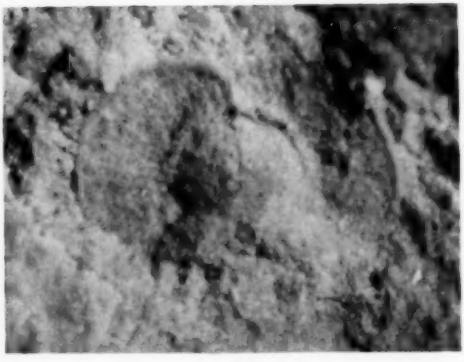


1A

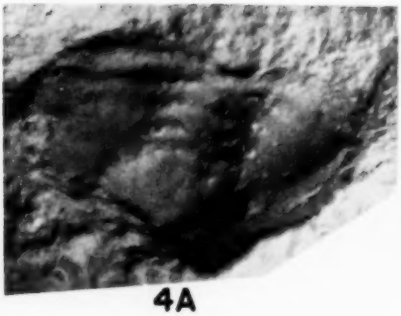


2

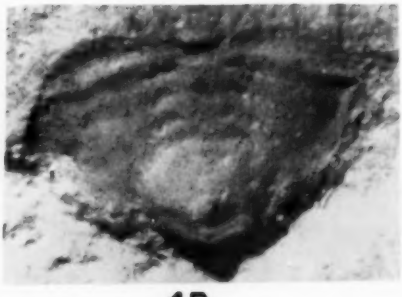
3



1B



4A



4B

LOCALITIES AND MEASURED SECTIONS

Outcrop Belt A

Locality No.: *Jester Creek I*, Harvey Co., Kansas (see: Tasch, 1958, for details). Slabs containing clam-shrimps and insect wings have since been found. The insect is assigned to the order Protoperlaria, family Lemmatophoridae (J.R.Z.).

Jester Creek II, Harvey Co., Kans., NE, SE, sec. 16, T. 24 S., R. 1 E. (west bank of creek) (I.R. = insoluble residue, followed by percent and any content of interest.)

Bed No.		*Feet*
21	Gradational irregular contact with soil, gray-black, blocky, waxy shale. I.R., 71.5%, evaporite crystals	1.25
20	Massive, waxy, black-gray shale, similar to bed no. 21 but more massive. Coconut-calcite parting at base; some green and gray shales; calcite partings at 0.45′ and 0.6′ respectively from top of bed; also calcite parting perpendicular to bedding along a joint, this parting being very thin and not continuous. I.R., 77.0%	1.10
19	Black, waxy, blocky-to-laminated shale; joint completely surrounded by black shale on all sides, sharp contact; thickness to base of this bed including the calcite joint system (I.R., 17% for the joint filling)	0.75
18	Blocky, black, waxy shale; upper 0.5′ calcite joint filling that ends in a thin calcite parting. I.R., 82.0%	1.10
17	Black, massive waxy shale as above, contains several thin calcite partings. I.R., 74.0%	0.90
16	Blocky-to-laminated black-to-gray waxy shale, contains irregular calcite-shale lumps showing eroded surfaces; some calcite partings. I.R., 53.4%	1.30
15	Jointed and cracked light gray, dense, slightly argillaceous limestone; weathers chalky white; contains centers of crystalline silica. I.R., 18.1%, evaporite flakes	0.15–0.20
14	Very thin-bedded, gray-brown-to-black waxy shale. I.R., 18.0%	0.15
13	Highly argillaceous limestone, thin-bedded. I.R., 23.5%, fragmentary ostracod valve	0.13
12	Brown-to-gray-brown waxy, platy shale; vertical joint extending length of bed contains one-quarter inch calcite parting. I.R., 65.0%, salt cast	1.20
11	Finely laminated-to-blocky greenish brown-to-brown shale. I.R., 72.0%	1.00
10	Blocky, grayish black-to-black waxy shale; upper 0.7 feet green-to-black shale with thin, brownish green bands; contains vertical joints filled with calcite. I.R., lower portion, 47.3%, ostracod valve; I.R., upper portion, 66.0%	2.15
9	Light gray argillaceous limestone, top surface jointed, shows concentric weathering between joints on both exposed and covered surface; many joints show coconut-calcite fillings. This bed was sampled every 5′ along 27′ length and then continued	

EXPLANATION OF PLATE 98

FIG. 1—*Bifarius comptae* Tasch, n. gen., n. sp. (a) Internal mold of xiphosuran dorsal shield; (b) cast of same. Holotype: W.U. 201, ×28.

2—*Stronglyocephalus charactis* Tasch, n. gen., n. sp. Xiphosuran dorsal shield; note paired arcuate slits anteriorly, and vertical indentations on cardiac lobe. Holotype: W.U. 202, ×36.

3—*Hypatocephala rugosa* Tasch, n. gen., n. sp. Ovate xiphosuran dorsal shield; note resemblance of cardiac lobe to trilobite glabella, protruding ring, and ophthalmic ridge reminiscent of trilobite palpebral lobes. Holotype: W.U. 203, ×8.

4—*Pringlia leonardensis* Tasch, n. sp. Triangular xiphosuran abdomen showing four axial furrows. (a) Slightly oblique view to emphasize bulbous posterior boss that tapers to blunt node-like spine; (b) dorsal view to show configuration, axial segments, boss and terminal spine. Holotype: W.U. 200, ×6.

Bed No.	*Feet*
on reverse slope where it was sampled every 9′ (see Text-fig. 4); top surface 9A° (see Text-fig. 4) fragmentary cast of hopper crystal. Top surface: *Isaura* (*Euestheria*) *harveyi* A & B; undeter. conchostracan genus and species I; middle surface: *I.* (*Eu.*) *harveyi* A & B, *I.* (*Eu.*) *harveyi harveyi;* undersurface: I. (Eu.) *harveyi* A & B, I. (Eu.) *harveyi wellingtoni;* I. (*Eu.*) *harveyi harveyi, Patelloidea limnesis* n. gen., IR., 15.0% (Pl. 1, figs. 4a,b)	0.35
8—Lithology same as bed 9, no conchostracans. I.R., 19.1%	0.20
7—Gray argillaceous limestone, grading into black, waxy shale, no conchostracans. I.R., 30.4%, shell fragment	0.02
6—Gray-to-black waxy, blocky shale, no conchostracans. I.R., 35.1%	0.46
5—Grayish-black shale, waxy, some markings (undeter.) on undersurface. I.R., 74.6%	0.21
4—Light gray waxy shale; between beds 4 and 5 there is a calcite parting. I.R., 32.9%, siliceous shell fragment, botryoidal, marcasite and limonite fragments; limonitic beak of a freshwater clam; evaporite crystals	0.35
3—This bed is arbitrarily divided into subdivisions a–d, of which 3a is the youngest: a—black, chunky-to-blocky waxy shale, deep oxide stain; b—black, waxy, blocky-to-laminated shale; c—soft, waxy black shale; d—laminated clay, black, blue, and brown clay mud, containing white silt streaks and small silt lenses at base and top; some laminated bands. I.R., 89.6%	0.90
2—Blocky, black, waxy shale, I.R., 63.0%, ostracod valve	0.65
1—Moist, waxy, blocky shale grading down to finely laminated, waxy shale, just below creek level; laminated shales have layer of silt between laminae. I.R., 58.7%	1.35
Total Measured Thickness	16.02

Locality No.: *Jester Creek III*, Harvey Co., Kans., N. line NW, SW, sec. 15, T. 24 S., R. 1 E.

Bed No.	*Feet*
13—Gray-green plastic clay, contains some calcite chips; forms irregular contact with soil. I.R., 41.0%, shell and mineral contaminants from Recent sediments	0.63
12—Blue-gray, waxy shale; blocky and crisscrossed by joints filled with iron oxide and calcite; weathers into concentric, lumpy nodules. I.R., 47.4%, pyritized fragment of minute snail	0.80
11—Calcareous argillite, fresh color is light blue-gray, weathers gray. I.R., 29.6%. Top surface and 5 mm. below top surface, *Isaura* (*Euestheria*) *harveyi* A	0.12
10—Plastic brown-gray-to-black-gray clay through gray-black thin-bedded shale at base. I.R., 62.0%, no fossils	0.20
9—Massive black-gray calcareous argillite, weathers white-gray; lower inch has same lithology as upper portion. Forms distinct weathering unit. I.R., 24.3%. Sampled for fossils as follows: a—0.19′ below top of bed. Top surface: *I.* (*Eu.*) *harveyi* A & B; undersurface: *I.* (*Eu.*) *harveyi* A. b—0.25′ below top of bed. Top and undersurface contain *I.* (*Eu.*) *harveyi* A & B. c—0.29′ (estimated) below top of bed. Top and undersurface contains: *I.* (*Eu.*) *harveyi* A & B. d—0.33′ below top of bed. Undersurface contains: *I.* (*Eu.*) *harveyi* B. e—0.35′ below top of bed. Undersurface contains: *I.* (*Eu.*) *harveyi* A & B.	
8—Thin-bedded black-gray shale; forms distinct weathering unit from overlying bed. I.R., 48.0%, red-streaked chert. No fossils	0.04–0.08
7—Light gray, slightly argillaceous limestone; weathers oxide brown and green-gray; forms distinct weathering unit. I.R., 28.6%	0.06
6—Waxy, gray-black shale, blocky, forms sharp contact with overlying limestone. I.R., 48.0%	0.09
5—Very waxy, gray-black shale; weathers in concentric nodules. I.R., 64.0%	0.10
4—Silty shale grading into calcareous partings. I.R., 23.0%	0.04
3—Lithology same as bed 5. I.R., 55.0%	0.10
2—Between two calcite partings, plastic gray clay with some black-gray shale nodules. I.R., 76.1%. Minute white siliceous tubes with coarse surfaces and shell fragments; round marcasite mass; siliceous tubes open at both ends	0.27
1—This bed is divided arbitrarily into two units: a—soft, gray-brown silty shale, deep oxide stain; calcareous nodules and black shale chips. I.R., 85.0% b—massive blue-gray waxy shale with several thin silty partings at base and below creek level. I.R., 38.8%	1.50
Total Measured Thickness	5.48–5.52

Locality No.: *Jester Creek IV*, Harvey Co., Kans., NE, SW, sec. 10, T. 24 S., R. 1 E.

Bed No.	*Feet*
22—Pink-white-gray (Tertiary) conglomerate containing large brown plastic clay shale chips; very sandy and crumbly on fresh face; contains red-to-tan chert and quartz pebbles; upper portion almost a pure sand, lower portion a conglomerate	0.99
21—Coconut-calcite partings; green stained; sharp contact with underlying shale. I.R., 8.3%	0.06
20—Waxy green plastic clay with thin-bedded shale, forms sharp contact with bed 19. I.R., 92.7%	0.46
19—Series of coconut-calcite partings ranging in thickness from $\frac{1}{4}$"–$\frac{3}{4}$". I.R., 2.3%	0.61
18—Plastic green-gray clay	0.17
17—Double calcite parting. I.R., 3.1%	0.05
16—Gray-black waxy shale, weathers light gray; lower $\frac{1}{4}$" a double calcite parting. I.R., 48.9%	0.55
15—Light blue argillaceous limestone, weathers white-gray; fractured; joints filled with vertical calcite partings which follow configuration of vertical face. I.R., 17.5%	0.10
14—Very thin-bedded gray-blue waxy shale. I.R., 52.0%	0.05
13—Double calcite parting. I.R., 2.34%	0.05
12—Very thin-bedded green-black shale. I.R., 55.0%	0.05
11—Light gray-blue argillaceous limestone; medium bedded; joints are not filled with calcite. Sampled for fossils as follows: a—top of bed 11—no conchostracans on top surface: *Isaura* (*Euestheria*) *harveyi* B on undersurface. b—$1\frac{1}{2}$" from top of bed 11—top surface and underface: *I.* (*Eu.*) *harveyi* B. c—2" from top of bed 11—top surface: *I.* (*Eu.*) *harveyi* A. d—$3\frac{1}{2}$" from top of bed 11—top and undersurface: *I.* (*Eu.*) *harveyi* A & B; undersurface: *I.* (*Eu.*) *harveyi harveyi*. e—4" below top of bed—top and undersurface; *I.* (*Eu.*) *harveyi* A & B; top surface: *I.* (*Eu.*) *harveyi harveyi*. I.R., 19.6%, chitinous molts	0.39
10—Very thin-bedded blocky, blue-gray-to-green-black shale; calcareous silt partings near base. I.R., 40.0%, limonitic crusts	0.42
9—Light blue-gray, blocky shale, with some thin-bedded shale near base. I.R., 30.5%, oxide crusts	0.70
8—Double calcite parting. I.R., 4.2%	0.04
7—Gray-black-to-gray-blue massive waxy shale, some fine calcareous partings and crystalline limestone nodules. I.R., 72.4%	0.80
6—Crystalline limestone partings in gray-blue shale. I.R., 31.0%, oxide crusts	0.04
5—Blocky, black-blue, waxy shale. I.R., 44.8%	0.20
4—Double calcite parting. I.R., 3.1%	0.06
3—Blocky, blue-gray-to-black waxy shale, ends in $\frac{1}{4}$" calcite parting. I.R., 32.5%	0.80
2—Siltstone and gray calcareous shale, thin-bedded; very fine calcite partings, closely packed. I.R., 55.4%	0.80
1—Distinctive light gray-white crystalline, highly argillaceous limestone (Note: crystalline limestone invades usual shale; probably the equivalent of coconut-calcite partings). Gray-black-to-blue-gray waxy shale, continues down to creek bed. I.R., 41.0%	0.16
Total Measured Thickness	7.54

Locality No.: *Jester Creek V*, Harvey Co., Kans., W line NE, SW, SE, sec. 10, T. 24 S., R. 1 E. (on S. creek bank).

Bed No.	*Feet*
24—Buff-brown, very pure sand, forms relatively sharp contact with underlying bed; light gray-green plastic clay, zone penetrated by living roots; a dark brown oxide stain streaks the clay; 2" above base of this bed, a very thin calcite parting. I.R., 83.0%	0.57
23—Successive coconut-calcite layers, thicker part towards base. I.R., 31.6%	0.14
22—Shale, same as bed no. 24, some hard calcareous or silicified crusts. I.R., 22.7%	0.16
21—Coconut-calcite parting. I.R., 4.6%	0.08
20—A successive series of coconut-calcite partings which have gone into solution form a single lithic unit; polygonal parting rises in relief from horizontal plane within body of the rock; deeply pitted; partings cause reticulation on exposed surface. I.R., 16.3%. Black iron oxide as in bed no. 19	0.37
19—Alternating coconut-calcite partings and finely laminated plastic gray-green clay. I.R., 24.2%. Botryoidal black iron oxide also disseminated in clay and as crusts	0.55

Bed No.	*Feet*
18—Same as bed no. 19, lower part laminated shale and some siltstone. I.R., 28.4%	1.10
17—Gray-black, blocky, waxy shale interbedded with calcite partings; upper 1½″ finely laminated, green-gray shale with fine calcite parting on top and bottom. I.R., 37.2%	0.45
16—Gray-drab plastic clay. I.R., 81.0%	0.16
15—Hard unit consisting of a series of calcite partings and shale. I.R., 30.7%	0.08
14—Series of gray plastic shales interbedded with calcareous partings. Upper 2½″ gray plastic shale; middle band of blue-gray, waxy shale; lower unit of plastic shale. I.R., 65.4%	0.75
13—Calcite partings. I.R., 2.6%	0.14
12—Gray-green plastic clay interbedded with calcareous partings; calcite partings at base pinch out upslope; other portions of partings continue. I.R., 26.0%	0.40
11—Gray argillaceous limestone; weathers white, fractured and jointed; 1½″ blue-gray plastic clay at base. Sampled for fossils as follows: a—top of bed: *Isaura* (*Euestheria*) *harveyi* A & B and *I.* (*Eu.*) *harveyi harveyi*. b—½″ below top of bed: *I.* (*Eu.*) *harveyi* A, *I.* (*Eu.*) *harveyi harveyi*. c—1″ below top of bed: fossils same as in bed 11a. I.R., 17.6%	0.22
10—Double coconut-calcite parting. I.R., 3.6%	0.12
9—Blue-black-to-gray-blue, blocky, waxy shale (I.R., 74.2%), interbedded with calcite partings particularly in lower portion. There are four distinct weathering units and these are argillaceous limestones. These were sampled as follows: 0.16′ below top of bed, argillaceous limestone, ½″ thick, I.R., 24.3%, subrounded silt and limonitic crusts; 0.53′ from top of bed, argillaceous limestone 2″ thick, I.R., 23.8%; 1.0′ from top of bed, argillaceous limestone 2″ thick, I.R., 18.2%, very thin-walled, chitinous structures embedded in clay residue; HF acid treatment of this residue yielded a quantity of translucent fragments speckled with opaque organic centers, probably arthropod; 1.23′ from top of bed, argillaceous limestone 1″ thick. I.R., 28.1%	1.65
8—Multiple calcite partings forming distinct ledge. I.R., 32.3%	0.14
7—Blue-gray, blocky and plastic clay interbedded with thin calcite partings. I.R., 46.6%	1.15
6—Gray-black, blocky, waxy shale. I.R., 81.0%	0.80
5—Silty shale, dirty green-brown, very thin calcite parting at top and base. I.R., 40.0%	0.40
4—Thinly laminated-to-blocky, silty shale, dirty green-brown-to-blue-black; blocky and waxy shale with thin calcite parting at base. I.R., lower blocky portion, 50.0%; upper silty portion, 67.5%	1.85
3—Black-gray, waxy-blocky shale, some laminated layers. I.R., 58.1%	0.80
2—Black shale interstratified with white, silty layers. I.R., 46.1%	0.12
1—This bed was sampled in three units: a—blocky-to-thin laminated shale, blue-black-to-red-brown and light gray. I.R., 92.8% 0.75′ b—silty, finely laminated shale, dirty gray. I.R., 77.0% 1.70′ c—blocky, waxy shale containing streaks and lenses of light gray clay. I. R., 66.7% 2.20′	4.65
Total Measured Thickness	16.85

Locality No.: *Jester Creek VI*, Harvey Co., Kans., SW, NE, SE, sec. 10, T. 24 S., R. 1 E. (in N. creek bank).

Bed No.	*Feet*
19—Relatively sharp contact with soil; unconsolidated sand and silt contains weathered pebbles of various composition. I.R., 62.0%	0.23
18—Calcareous conglomerate containing clay and other pebbles, shale chips; at base, there is a coconut-calcite layer which is conformable with the conglomerate; shale chips are green and red giving the characteristic color, which is dominantly pink on the fresh surface. I.R., 24.0%	0.45
17—Finely laminated drab-gray shale and silt. I.R., 80.0%	0.19
16—Light gray, medium bedded, blocky and waxy shale, with some thin partings dispersed throughout. I.R., 59.4%	0.83
15—White gray argillaceous limestone, weathers white, surface fractured and jointed. Sampled for fossils as follows: a—top surface: *Isaura* (*Euestheria*) *harveyi* A; undersurface, 0.06′ from top of bed: *I.* (*Eu.*) *harveyi* A & B. b—top surface: *I.* (*Eu.*) *harveyi* A & B and *I.* (*Eu.*) *harveyi harveyi*; undersurface, 0.09′ from top of this unit: *I.* (*Eu.*) *harveyi* A & B.	

Bed No.	Feet
c—top surface: *I.* (*Eu.*) *harveyi* A & B; undersurface, 0.09′ from top of this unit; same fossils as on top surface. I.R., 18.1%	0.24
14—Blue-black, gray-black, blocky, waxy shale. I.R., 56.0%	0.17
13—White-to-blue-gray argillaceous limestone, weathers white, no fossils. I.R., 30.0%	0.15
12—Light gray blocky, waxy shale. I.R., 32.0%	0.25
11—Light gray argillaceous limestone. Forms distinct weathering unit; no fossils. I.R., 26.3%	0.08
10—Black-blue-to-gray waxy and platy shale. I.R., 47.2%	0.04
9—Argillaceous limestone grading into gray-black waxy shale. A distinct weathering unit. I.R., 33.3%	0.04
8—Blocky, waxy shale, gray-black-to-green-gray. I.R., 58.6%	0.08
7—Light gray argillaceous limestone; a distinct weathering unit. I.R., 16.0%, limonitic crusts	0.10
6—Alternating thin argillaceous limestone and blue-gray shale; (a) argillaceous limestone (b) argillaceous limestone near base. (I.R. for 6a, 40.5%; for 6b, 30.0%)	0.55
5—Double coconut-calcite parting. I.R., 27.8%	0.02
4—Thin, gray-blue-to-black shale, waxy; siltstone with 1.4″ calcite parting at base. I.R. (shale, etc.), 63.0%, partings, 18.0%	0.92
3—Blocky, waxy, blue-gray and gray-black shale. I.R., 46.5%	1.10
2—Blue-gray crystalline limestone, cavernous. I.R., 26.7%	0.06
1—Upper unit alternating siltstones and thin-bedded black, silty shales, grading into typical blue-black waxy shale which grades down into siltstone and, in turn, grades down into black silty shale. I.R. as follows: (a) siltstone, 76.2% (b) shale, 82.5% (c) siltstone, 26.8% (d) shale, finely laminated, with evaporite crystals on surface, 68.3%	2.25
Total Measured Thickness	7.75

Locality No.: *Jester Creek VII*, Harvey Co., Kans., S. line NE, SE, sec. 10, T. 24 S., R. 1 E.

Bed No.	Feet
11—Unconsolidated sand, light brown, some light clay; forms fairly sharp contact with underlying bed; weathered. I.R., 81.0%	0.60
10—Hard, consolidated conglomeratic bed; very sandy, contains shale chips; base with weathered coconut-calcite parting ¼″ thick. I.R., 62.0%	0.25
9—Green, plastic clay, several coconut-calcite layers; basal layer, a double coconut-calcite parting (0.08′). I.R., 7.0% (calcite partings); 85.5% (clay)	0.57
8—Drab-green plastic clay and shale, several calcite partings. I.R., 84.0%	1.75
7—Green-gray waxy, blocky shale. I.R., 73.1%	0.61
6—At top, ¼″ calcite layer; lithology same as above; lower calcite parting, ¼″. I.R., 67.3%	0.41
5—Double calcite parting; upper parting deeply weathered and shaly. I.R., 10.2%, unidentifiable shell (?) fragments; banded and needle-shaped clear silica from calcite partings	0.14
4—Thin-bedded light gray shale. I.R., 56.4%	0.27
3—Light gray argillaceous limestone sampled for fossils as follows: a—top surface: *Isaura* (*Euestheria*) *harveyi* B; 10.0 mm. below top of 3a: *I.* (*Eu.*) *harveyi* A. b—13.0 mm. below top of this unit: *Stagnestesta solitaria* (Pl. 1, fig. 5). 14.0–15.0 mm. respectively below top of this unit: *I.* (*Eu.*) *harveyi* A.I.R., 33.0%	0.10
2—Gray, argillaceous limestone grading down into plastic gray-blue shale. Top surface: *I.* (*Eu.*) *harveyi* A. I.R., 33.0%	0.10
1—Blue-gray, waxy and blocky shale down to creek bed. I.R., 35.0%	0.10
Total Measured Thickness	4.80

Locality No: *Jester Creek VIII*, Harvey County, Kans., SE, SE, sec. 10, T. 24 S., R. 1 E., along creek bed near section corner.

Bed No.	Feet
10—Coarse-to-fine sand, fairly even contact with soil. I.R., 60.0%	0.31
9—Coarse, pebbly conglomerate with shale chips and calcite partings, conformable to bed at base. I.R., 45.0%	1.82

Bed No.	*Feet*
8—Gray-to-light gray-green plastic clay with $\frac{1}{2}$″ calcite parting in the middle. I.R., 71.0%	0.28
7—Gray argillaceous limestone, weathers white; massive, blocky-to-medium bedded. I.R., 38.5%, black oxide crusts	0.55
6—Same lithology as bed 7. Sampled for fossils as follows: a—top: *Isaura* (*Euestheria*) *harveyi* A & B; 15.0 mm. below top of this unit: *I.* (*Eu.*) *harveyi* A. b—top: *I.* (*Eu.*) *harveyi* B. I.R., 34.8%, carbonized internal mold, pustulate, coiled at one end, possibly molluscan	0.23
5—Drab-green shale. I.R., 68.0%, carbonized fibrous wood fragment; black; oxide molluscan (?) fragment	0.04
4—Light gray argillaceous limestone. I.R., 38.5%	0.17
3—Drab-green shale; thin calcite parting at base. I.R., 64.2%	0.14
2—Alternating thin limestone and shale; two argillaceous limestone layers, $1\frac{1}{2}$″ each separated by shale; basal $\frac{1}{2}$″ calcite parting. I.R., 26.0%	0.50
1—Drab-black plastic, blocky and waxy shale; leading down to creek bed; blue-black, gray-black massive shale; many small calcite partings grading into silty material near creek level. I.R., 73.7%; black oxide crusts, ostracod (?) valve, shell fragment	——
Total Measured Thickness	4.04+

Locality No.: *Jester Creek IX*, Harvey County, Kans., E line NW, NW sec. 13, T. 24 S., R. 1 E. (2.4 miles east of Jester Creek I, S. field on east road to Annelly).

Bed No.	*Feet*
6—Massive bluish gray limestone, pitted, limonitic stain; weathers light gray; ledge maker. I.R., 9.0%	0.45
5—Plastic brown-gray shale, $\frac{1}{16}$″ calcite parting at base. I.R., 67.0%	1.22
4—Waxy, blocky, green-gray shale. I.R., 77.0%	0.63
3—Plastic, green-gray and black moist shale. I.R., 58.0%	1.10
2—Bluish, light gray argillaceous limestone. Fossils only on top surface: *I.* (*Eu.*) *harveyi* A & B. I.R., 22.0%	0.30
1—Drab, waxy shale; lower portion contains black shale chips. I.R., 70.0%	2.20+
Total Measured Thickness	5.90+

Locality No.: *Jester Creek X*, Harvey County, Kans., W line SW, NW, sec. 28, T. 24 S., R. 1 E. (Highway 81, $1\frac{3}{4}$ miles north of Sedgwick Co. line, under bridge).

Bed No.	*Feet*
——Slumped soil bank, clay with pinkish silt	
17—Coconut-calcite, double band. I.R., 6.0%	0.10
16—Plastic gray clay with four-to-five $\frac{1}{16}$″ partings that stand out and weather limonitic. I.R., 64.0%	0.25
15—Coconut-calcite parting. I.R., 6.0%	0.15
14—Plastic gray clay; deep limonitic stain. I.R., 85.0%	0.47
13—Black, hard argillaceous limestone; fine calcite parting in contact with limestone above and below. I.R., 37.0%, subround quartz silt	0.15
12—Gray, plastic clay; deep oxide stain, contains many fragments of black plastic clay. I.R., 70.0%	0.32
11—Alternating bands of coconut-calcite and gray, limonitic, plastic clay shale; slump and solution have fused calcareous partings into a reticulate pattern that cuts across the bedding; lower portion of shale appears to be finely laminated; all the shale very waxy. I.R., 26.0%	2.27
10—Thin-bedded-to-platy gray-black plastic shale. I.R., 38.0%	1.16
9—$\frac{1}{4}$″ calcite partings. I.R., 22.0%	0.04
8—Hard, black plastic shale, weathers brown and green, very calcareous. I.R., 63.0%	0.18
7—Same lithology as bed 8 but platy. I.R., 68.0%, salt casts	0.12
6—Argillaceous limestone; undersurface irregular; top surface smooth; forms distinct weathering unit. I.R., 14.0%	0.04
5—Shale. Upper third weathers light gray, grading into finely laminated-to-medium-bedded, middle third weathers darker black-gray, waxy, platy shale; argillaceous limestone at top thins and thickens; lower third, finely laminated-to-platy, waxy shale grading into black, blocky shale. Above units contain many interspersed calcite partings. I.R., 84.0% (top third); 75.0% (middle third); 65.0% (lower third)	2.20
4—Blocky, gray-black shale, plastic; at base there is a thin, hard, black calcareous argillaceous unit; clean face of unit is speckled with evaporite. I.R., 86.0% (top), 32.0% (base)	1.20

Bed No.	*Feet*
3—Same lithology as above; streaked white on fresh face; contains some hard, calcareous nodules. I.R., 80.0%	0.88
2—Lithology same as above; very blocky and waxy; lower unit of this bed is a finely laminated argillaceous siltstone. I.R., 53.0% (lower siltstone), 40.0% (shale)	1.26
1—Same blocky and waxy shale as above with ¼″–½″ thick whitish, silty clay; this occurs near the top of the unit. I.R., 40.0% (lower portion); 48.0% (upper portion). Hard, nodular black shale with evaporites; distinct limonitic parting near upper silt; unmeasurable due to cover down to creek level. I.R., 32.0%	1.20
Total Measured Thickness	11.99

Locality No.: *Jester Creek XI*, Sedgwick Co., Kans. S line SW, NW, sec. 5, T. 25 S., R. 1 E. (½ mile south of Sedgwick Co. line and almost one mile west of Highway 81 on Gooseberry Creek).

Bed No.	*Feet*
——Brown, clayey soil	
30—Coconut-calcite parting directly in contact with soil	0.08
29—Brownish-green plastic clay underlain by coconut-calcite parting. I.R., 85.0% (clay)	0.40
28—Calcite parting: upper portion 0.08′, lower portion 0.15′; double parting but no break between them as is usual. I.R., 3.0%	0.23
27—Drab-green plastic clay, at the base ½″ calcite parting added to thickness of this unit. I.R., 80.0%	0.25
26—Buff-pink-to-white plastic clay with irregular shaped calcite nodules. I.R., 33.0%	0.25
25—Hard calcite band containing solution-fused calcite partings. I.R., 15.0%	0.20
24—Calcareous partings interbedded with drab-green shale. I.R., 6.0% (partings)	0.26
23—Thin-bedded, green-gray plastic clay, weathers brown. I.R., 90.0%	0.55
22—Plastic, gray-black clay; upper one inch a double calcite parting. I.R., 94.0% (clay), 7.0% (partings)	1.50
21—Light gray plastic clay; silt grading down into gray-black, blocky, and plastic clay; two calcite partings ½″ thick, one on top and one at 0.8′ above base of bed 21. I.R., 64.0% (top), 57.9% (lower part)	1.90
20—Light gray argillaceous limestone. On lower slope below this bed, debris from bed 20 contained conchostracans. Bed 20 sampled for conchostracans and associated molluscan fauna as follows: Top of bed 20—*Permoplanorboidea primis*, n. gen., n. sp. (Plate 97, fig. 1) 6 mm. below top—*Isaura* (*Euestheria*) *harveyi* A & B; *Rostrotortus dissimilis*; undeter. pelecypod genus and species No. 1 7 mm. below top—*Isaura* (*Eu.*) *harveyi* A. 9 mm. below top—*Isaura* (*Eu.*) *harveyi* B. 11 mm. below top—*Isaura* (*Eu.*) *harveyi* B. 20 mm. below top—*Isaura* (*Eu.*) *harveyi* B. 27 mm. below top—*Isaura* (*Eu.*) *harveyi* B. 34 mm. below top—*Isaura* (*Eu.*) *harveyi harveyi*. 36 mm. below top—*Isaura* (*Eu.*) *harveyi* B. 38 mm. below top—*Isaura* (*Eu.*) *harveyi* A. I.R., 24.8%	0.12
19—¼″ coconut-calcite partings. I.R., 7.0%	0.08
18—Waxy, drab-brown, blocky shale; a thin calcite parting 0.45′ from base; along plane of parting several nodular chunks of calcite occur. I.R., 67.0%	1.00
17—Coconut-calcite partings ⅜″ thick. I.R., 24.0%	0.06
16—Gray-black waxy-to-blocky shale; several small calcite partings throughout unit; limonitic stain along such partings. I.R., 59.0%	1.00
15—Double coconut-calcite parting. I.R., 7.0%	0.12
14—Drab-brownish blocky shale, several thin partings at the base; some very thin calcite joint fillings perpendicular to bedding. I.R., 69.0%	1.00
13—Hard crystalline calcareous-evaporite; surfaces above and below irregular and undulating. Fresh surface pinkish against gray-black background (gypsum?); pink material speckled and appears to be interstitial fillings. I.R., 41.0%, evaporite crystals	0.08
12—Shale same as bed no. 14. I.R., 76.0%	1.00
11—Silty, calcitic, hard bed with one inch calcite partings. I.R., 18.0%	0.08
10—Thin-bedded-to-platy gray-black plastic shale; contains hard, calcareous, silty unit in middle third. I.R., 50.0%	1.50
9—Shale, same as bed no. 10; contains hard, calcareous nodules up to 2″ in diameter and several thin calcite partings. I.R., 83.0%	1.45+

Bed No.	*Feet*
8—Same lithology as bed no. 9. I.R., 80.0%	1.05
7—(Offset)—gray-black laminated shale, grading upward into bed no. 8. I.R., 54.0%	0.90
6—Upper basal limestone: crystalline, dense, creamy white-gray, thin-bedded. I.R., 4.2%	0.52
5—Blocky, green moist shale, some thin-bedded shale, same lithology; near base calcite parting forming thin hard unit; lower portion turns gray in contact with underlying limestone. I.R., 94.0%	1.68
4—Middle basal limestone; bluish gray, medium-to-thin-bedded, slightly crystalline, shows banding (lamination) toward top. I.R., 8.0%	0.45
3—Black-gray laminated shale grades downward into lower basal limestone; ½″ limestone in sharp contact with laminated shale. I.R., 37.0% (shale), 11.0% (limestone)	0.17
2—Finely laminated shale, ¼″ thick; grayish blue-black. I.R., 20.0%	0.02
1—Banded argillitic limestone. I.R., 10.0%, marcasite crusts, limonitic chunks and yellow-brown chitinous molt fragments	0.08
Total Measured Thickness	17.98

Outcrop Belt B (Harvey County portion only; belt extends into Marion County).

Locality No.: *North Harvey I*, Harvey County, Kansas; center/S. line, sec. 5, T. 22 S., R. 1 E. (1.5 miles east of Highway 15 and 1.0 mile south of Harvey-Marion County line, 660 feet plus or minus north of road in bank of Sand Creek tributary.)

Bed No.	*Feet*
——Red, blocky shale in rises back in field; unable to establish contact due to slump	
6—Plastic, green shale; sharp contact with underlying hard beds	1.59
5—White, argillaceous limestone, weathers gray-buff, contains numerous smooth, minute, green shale pellets. Sampled for conchostracans, although no separation by generations was feasible: *Isaura* (*Euestheria*) *harveyi* A & B; *I.* (*Eu.*) *harveyi harveyi*	0.12
4—One inch thick green-blue plastic shale and thin ¼″ partings; some pink gypsum in calcite partings; one parting directly under bed no. 5	0.10
3—Argillaceous limestone; conchostracan-bearing debris of bed no. 5 found at this level	0.09
2—Waxy shale, weathers light gray, green-gray-drab on fresh surface; platy and blocky	0.65
1—Light gray shale grading down into dark blue-black, platy, waxy and blocky shale. Thin coconut-calcite partings numerous	3.00+
Total Measured Thickness	5.55+

Locality No.: *Marion IIIA*, Harvey-Marion Counties, Kans. 1.7 miles east of Highway 15 on Harvey-Marion County line. Road ditch on north side of road and bank on south side of road.

Bed No.	*Feet*
7—Thin-bedded, greenish gray argillaceous limestone; jointed; no fossils observed. Interbedded between some of the thin argillaceous beds are some very thin plastic green shales; toward base of this unit, very thin coconut-calcite partings overlain and underlain by gray plastic shales. (In section 100 feet north in field, gypsum observed between calcite partings)	1.00
6—Gray-green plastic shale; irregular contact with underlying red shale; fragments of greenish stained hard calcite partings near middle of unit—probably fragments from overlying bed	1.20
5—Red shale, blocky	0.55
4—Blocky, plastic gray-green shale; thin calcite partings, fragmentary	0.91
3—⅛″–1″ calcite and gypsiferous partings immediate underlain by moist, blocky, plastic, light green shale	0.04–0.08
2—Light green shale; blocky, plastic, moist. A single well preserved valve of *Isaura* (*Euestheria*) *harveyi* A on undersurface of bed 2 (i.e., the basal blocky portion of this bed)	0.95
1—Subdivided into two portions:	
(a) Insect bed: white weathering yellow, oxide stain in joints; light gray, chalky argillaceous limestone, some evaporite crystals; contains insect fossils; small, smooth green shale chips in interior of rock on one plane (ex.: in one sample in a one-inch slab this green chip and pellet zone was ⅜″ from the base and in this same position in the slab, insect fossils were found). Insects include: Protorthoptera, Odonata, Megasecoptera (orders identified by J.R.Z.). Other fossils: *I.* (*Eu.*) *harveyi* A, reptilian fragments, fragments of carbonized wood; and undetermined pelecypod fragments	0.07
(b) Light green plastic shale of same lithology as bed no. 2; covered; thickness	

Bed No.	*Feet*
estimated	2.00±
(Note: silicified wood fragment found in bank above insect horizon on south side of road which adjoins a cultivated field)	
Total Measured Thickness	6.72±

Outcrop Belt C

Locality No.: *Annelly VIII*, Harvey County, Kans. S line, SW, SE, sec. 16, T. 22 S., R. 2 E. (1 mi. N. of Annelly VII and 0.3 mi. west of Hwy 835).

Bed No.	*Feet*
3—Sharp contact with overlying soil; medium-to-thin-bedded, drab, creamy gray limestone; lower portion more argillaceous; weathers light gray; no fossils observed	1.12
2—Light gray-blue-to-drab, hard, dense limestone, irregular upper surface; salt pseudomorphs upper portion; sampled for fossils as follows: Upper portion: *Isaura* (*Euestheria*) *harveyi* B; *I.* (*Eu.*) *harveyi harveyi; Echinestheria annellya*, n. sp.; undet. plant (?) fossil. Middle portion: Unidentified half-spindle-shaped fossil fragment; *I.* (*Eu.*) *harveyi* B; new pelecypod genus and species; *Rostrotortus dissimilis* (Pl. 97, fig. 7). Lower portion: *Pringlia leonardensis*, n. sp., of xiphosuran, three fragments consisting of molds and cast of abdominal shield bearing annulated axis (Pl. 98, fig. 4a–b)	0.30
1—Blocky, gray-green, waxy shales down to bottom of road cut	1.40
Total Measured Thickness	2.82

Locality No.: *Annelly VII*, Harvey County, Kans. Center of S. line, sec. 20, T. 22 S., R. 2 E. (1.5 mi. west of Hwy 835 and about ¼ mile east of Walton, cut in N. side of road).

Bed No.	*Feet*
9—Sharp contact with overlying red-brown soil; buff weathering, gray-buff argillaceous limestone, no visible fossils; weathers out in round, flat nodules	0.58
8—Platy, argillaceous limestone, creamy white and gray-blue	0.26
7—Thin-bedded, blocky-to-plastic gray-drab shale	0.47
6—Thin-bedded, platy, argillaceous limestone, white weathering, buff-gray interior	0.44
5—Gray-blue weathering, buff-gray on fresh surface, argillaceous limestone; jointed, thin-bedded. (Cf. bed 2, Ann. VIII). Sampled for fossils as follows: 0.3″ below top of Bed No. 5: *Isaura* (*Euestheria*) *harveyi* A & B. 0.75″ below top of Bed No. 5: *I.* (*Eu.*) *harveyi* A & B, *Echinestheria annellya* (these specimens are ⅓ the width of *I.* (*Eu.*) *harveyi* A & B found on the same surface); one slab 0.7″ below top of bed no. 5 contained very small mudcrack casts on same surface as *I.* (*Eu.*) *harveyi* B. 0.90″ below top of bed no. 5: *I.* (*Eu.*) *harveyi* B. 1.30–1.40″ below top of bed no. B: *I.* (*Eu.*) *harveyi* B. At unknown depth below top of bed no. 5, an incomplete fragment of an apparently segmented axis (?), possibly arthropod	0.35
4—Same lithology as bed no. 5; no fossils observed	0.30
3—Brown-blue, platy-to-plastic shale with ½″ calcareous parting halfway from base	0.95
2—Gray weathering, light gray, faintly blue on fresh surface, very hard and massive limestone, clay component negligible; no visible fossils	0.55
1—Shale; calcareous parting 0.63 feet from top; green-blue, soft, moist, plastic-to blocky shale	3.00+
Total Measured Thickness	6.90+

Locality No.: *Annelly IV*, Harvey County, Kans. S line, SE, SE Sec. 5, T. 23 S., R. 2 E. (2.0 mi. N. of Annelly ID and 1.1 miles west of Hwy 835).

Bed No.	*Feet*
8—Scattered and eroded fragments only. Conchostracan valves in light gray argillaceous limestone debris; upslope in roadcut. *Isaura* (*Euestheria*) *harveyi* A & B; *Echinestheria annellya*. (Thickness of bed no. 8 is unknown; the stratigraphic interval above bed no. 7 to base of bed no. 8 is uncertain. Definitely the C_2 horizon found elsewhere in this area)	——
7—Series of thin, hard, light gray-greenish blue argillaceous limestone; thin-bedded with some interbedded plastic shales; no visible fossils. This bed is overlain by a slump bank containing soil and debris of same composition	0.55

Bed No.	*Feet*
6—Drab, platy and blocky shale forming steep banks along creek bed	9.82
5—Massive light gray, deeply weathered argillaceous limestone; deep limonitic stain; numerous small cavities; some plant debris not clearly defined	0.55
4—Light gray-green plastic and blocky shale; upper ½″ contains a discontinuous carbonized band ¼″ thick	0.45
3—Blocky, massive calcareous shale; weathers tan-brown; gray-buff on fresh surface; upper 0.3 foot forms a distinct weathering unit; bed cut by numerous vertical thin calcite partings	1.10
2—Conchostracan and clam bed: platy-to-thin-bedded, gray-buff argillaceous limestone; clams and conchostracans in upper part include: *I.* (*Eu.*) *harveyi* B; numerous badly eroded valves of *Productae dunbaris*, (Pl. 97, fig. 9); slightly laminated in lower portion. (This bed is equivalent to bed no. 4, Annelly IA)	0.25
1—Drab, gray-weathering shale; very blocky shale grades down to drab blue shales at creek level	3.50+
Total Measured Thickness	12.47+

Locality No.: *Annelly III-A*, Harvey County, Kans. S line, SE, SW, sec. 9, T. 23 S., R. 2 E. (1 mile north of Annelly I-D and 0.6 mile west Hwy 835).

Bed No.	*Feet*
14—Drab, plastic shale, fairly sharp contact with overlying soil and underlying limestone; light gray-blue in lowermost portion; underlying limestone forms undulating surface on which this bed rests	1.95
13—Hard, nodular limestone, weathers white, no visible fossils; light gray-green on fresh surface. (These beds are equivalent of upper beds at Annelly I-A). Numerous small cavities and interior geodes; limonitic cement in cracks; a series of nodular layers each ¼″–1.00″ thick; some large chunks (nodular) serially connected; few thin shale partings; thin shale parting at base about 0.2 foot thick	1.58
12—Buff gray, hard, argillaceous limestone, contains some carbonaceous plant material; weathers in jointed blocks	0.15
11—Platy-blocky drab shale, black-gray streaks, some calcareous nodules, hard	0.45
10—Drab, gray calcareous argillite, some plant material	0.11
9—Hard, argillaceous limestone; light gray, drab; weathers white-gray; carbonized plant fragments; *Aclistochara* sp., *Isaura* (*Euestheria*) *harveyi* B	0.08
8—Drab, gray shale	0.02
7—Gray, drab argillaceous limestone; fresh surface drab; high spire gastropod genus and sp. undet. No. 1 (Pl. 97, fig. 2); *Productae dunbaris* (Pl. 97, fig. 9); carbonized leaf cast; seed coat	0.30
6—Brown-gray plastic clay	0.17
5—Light, gray-weathering, hard, argillaceous limestone, fresh surface buff-gray; *Aclistochara* sp., *I.* (*Eu.*) *harveyi* A & B; seed coats abundant; *Myalina meeki* Dunbar; *Wellingtonia producta* (Pl. 97, fig. 11); carbonized leaf fragments; poorly preserved ostracod valves	0.06
4—Blocky, drab-green soft shale; very blocky and harder in lower portion which contains: *Aclistochara* sp., carbonized leaf fragments; algal thallus(?)	1.50
3—Hard, gray weathering argillaceous limestone, thinly bedded and platy in midportion which contains: *Echinestheria annellya* and *I.* (*Eu.*) *harveyi* A & B	0.24
2—Shale, covered (level from top of bed no. 3 to lower conchostracan bed)	13.84
1—Hard, blue-gray argillaceous limestone; remnants of hopper crystals; (this bed equivalent to bed no. 4, Annelly I-A). Sampled for fossils as follows: 1″ below top of bed: *I.* (*Eu.*) *harveyi* A & B. 1.2″ below top of bed: *I.* (*Eu.*) *harveyi* A & B and reptilian scales (Note: Local farmer reports silicified wood debris in field; about 2 feet below Bed No. 3, a thin, hard, crystalline, unfossiliferous limestone was observed; non-persistent).	0.23
Total Measured Thickness	20.68

Locality No.: *Annelly I-D*, Harvey County, Kans. S line, SW, SE, sec. 16, T. 23 S., R. 2 E. (N and S roadbank going east on Hwy 570; 0.3 mile north of Annelly I-A).

Bed No.	*Feet*
9—Plastic clay, calcareous and limonitic stain; irregular contact with soil	0.70
8—Hard, deeply eroded argillaceous limestone; weathering surface whitish-to-limonitic brown; fresh surface blue-gray-to-dark gray; some fragments contain: *Echinestheria annellya; Isaura* (*Euestheria*) *harveyi* A & B; minute carbonaceous leaf fragments	

Bed No.	*Feet*
widely disseminated. (Not possible to uncover this bed in continuity due to weathering and slump). Silicified wood and chert debris found on slope from this horizon downward	0.25
7—Gray, limonitic, plastic clay	0.27
6—Hard, crystalline, deeply eroded limestone, limonite stain	0.22
5—Gray-brown, plastic clay, silty, oxide stain	0.27
4—Hard, very thin sequence of calcite partings, deep limonitic weathered zone	0.16
3—Blocky, waxy, soft, light gray-drab plastic shale	1.54
2—Light gray weathering, argillaceous limestone; platy; hopper crystals; conchostracans and mollusks. (Note: this bed is the equivalent of bed no. 4, Annelly I-A). Sampled as follows: 1″ from top of Bed No. 2: *I.* (*Eu.*)*harveyi* B. 1.2″ from top of Bed No. 2: *Permoplanorboidea primus*, n. gen., n. sp. (Pl. 97, fig. 1) 2.2″ from top of Bed No. 2: *I.* (*Eu.*) *harveyi* B; reptilian scale. 3.0″ from top of Bed No. 2: *I.* (*Eu.*) *harveyi* A & B. 3.5″ from top of Bed No. 2: *I.* (*Eu.*) *harveyi* A. In addition, from fragments of bed no. 2, of unknown depth below top: carbonaceous leaf fragments; *Productae dunbaris* (Pl. 97, fig. 9); *Wellingtonia producta* (Pl. 97, fig. 11); insect wing together with *I.* (*Eu.*) *harveyi* B and several reptilian scales on same plane as conchostracans	0.29
1—Plastic, blocky, blue-gray-brown shale down to base of roadcut	3.00±
Total Measured Thickness	6.70±

Locality No.: *Annelly I-C*, same locality as Annelly I-A but offset to northwest to obtain the carbonized zone exposed here but not exposed at Annelly I-A or I-B. On cliffed face fronting creek.

Bed No.	*Feet*
9—Hard, nodular-weathering calcite-crust zone. Impression of high-spired gastropod, genus and species undetermined, No. 1	0.05
8—Hard, light gray calcareous argillite, fragments of carbonized wood; undersurface of this bed bears hopper crystals	0.08
7—Carbonized wood and plant zone; one carbonized log 5 feet plus in length; zone occurs in drab, soft, waxy shale containing carbonized plant material; a hopper crystal zone occurs at the contact between this zone and the overlying bed no. 8	0.30
6—Tan, plastic, blocky shale; very blocky in lower portion; forms very distinct contact with overlying carbonized zone. Fossils include: brown and carbonized plant debris; *Permoplanorboidea primus* (Pl. 97, fig. 1)	0.15
5—Hard argillaceous limestone; white weathering gray-blue conchostracan and clam bearing; upper surface contains hopper crystals; conchostracans in upper $\frac{1}{4}$″–$\frac{1}{2}$″. Fossils include: (near middle of bed) reptilian scale, *Elliptoidea vulgaris* (Pl. 97, fig. 10), *Productae dunbaris* (Pl. 97, fig. 9), *Isaura* (*Euestheria*) *harveyi* A & B, *Echinestheria annellya*, sparse brown plant debris, and a possible eurypterid (very poorly preserved and barely distinguishable)	0.28
4—Tan weathering hard argillaceous limestone; thin-bedded and platy weathering; fresh surface tan-gray-blue; salt pseudomorphs in middle portion; fossils include: *Echinestheria annellya*; *I.* (*Eu.*) *harveyi* A & B; *Productae dunbaris* (Pl. 97, fig. 9) (limonitic); xiphosuran (?) sp. undet.	0.50
3—Shale, (level to top of black gypsiferous shale) covered	6.30
2—Gypsiferous shale, covered to creek level	——
1—Gypsum in creek bed	——
Total Measured Thickness	7.66

Locality No.: *Annelly I-B*, Harvey County, Kans. Same locality as Annelly I-A but offset to east to include Tertiary conglomerate in section.

Bed No.	*Feet*
4—Tertiary conglomerate; cross-bedded conglomeratic sandstone; weathers along cross-bedding; caprock of the area	2.20
3—Gray-green-to-plastic gray shale	2.97
2—Hard, gray-tan argillaceous limestone bearing conchostracans; fossils include: *Isaura* (*Euestheria*) *harveyi* A & B (all conchostracan valves are crinkled, suggesting desiccating conditions); carbonized seed coats; abundant amber colored-to-reddish brown reptilian fragments including: conical teeth, one fragment of a small jaw bearing conical teeth, spines, scales, skull plate fragments, etc.; carbonized wood	

Bed No.		*Feet*
	fragments; two unidentifiable mollusks represented by a large shell fragment bearing molluscan sculpture and one large impression (possibly gastropod) bearing molluscan sculpture	0.08
1	—Shale, covered. Level to top of lower conchostracan bed (equivalent to bed no. 4, Annelly I-A)	7.87
	Total Measured Thickness	13.12

Locality No.: *Annelly I-A*, Harvey Co., Kansas. NW, NE. sec. 21, T. 23 S., R. 2 E. (about 5.6 miles east of city limits of Newton and 0.3 miles south of Hwy 570).

Bed No.		*Feet*
20	—Nodular argillaceous limestone weathers white; irregular contact with overlying soil in most places; in others, a very sharp contact; badly weathered and fractured	1.10
19	—Light brown-yellow plastic clay, some carbonate streaks	0.26
18	—Hard, argillaceous limestone, weathers bluish white; fresh surface, slightly blue-gray; no visible fossils	0.27
17	—Brown, plastic shale	0.12
16	—Hard, argillaceous limestone, weathers drab; plant material and carbonized fragments	0.18
15	—Drab, plastic-to-laminated shale	0.15
14	—Drab, hard, argillaceous limestone; fresh surface light gray; fossils include: *Elliptoidea vulgaris* (Pl. 97, fig. 10), *Echinestheria annellya*, high-spired gastropod, genus and species undet. No. 1 (Pl. 97, fig. 2), *Rugoplanorboidella sedgwickii* (Pl. 97, fig. 3), *Productae dunbaris* (Pl. 97, fig. 9), reptilian plates, *Myalina meeki* D. (Pl. 97, fig. 6), carbonized wood fragments, leaf and stem impressions	0.12
13	—Drab, green-blue plastic shale	0.22
12	—Hard argillaceous limestone; fresh surface light tan; weathering white-gray; no visible fossils; thin calcite parting at base	0.14
11	—Light tan-gray plastic and blocky shale	0.73
10	—Hard, calcareous argillite; shows laminations distinct from shales above and below	0.07
9	—Blocky, tan-gray calcareous shale; slightly waxy	0.32
8	—Drab-gray-blue plastic shale	1.40
7	—(Level from base of bed no. 10 to top of lower conchostracan bed no. 4. Interval in between exclusive to bed no. 9 is undifferentiated gray-blue plastic shale). Corrected thickness	7.05
6	—Drab-to-blue-gray argillaceous limestone bearing conchostracans, etc.; thickness variable; breaks in sheets. Fossils include: 1.7 mm. below top of bed, *Isaura* (*Euestheria*) *harveyi* B; from undertermined depths below top of bed, *I.* (*Eu.*) *harveyi* A, reptilian scale and conical tooth; carbonized and non-carbonized wood and plant fragments; carbonized seed coat; xiphosuran genus and species, *Bifarius comptae*, n. gen., n. sp. (Pl. 98, fig. 1) (2 cephalons) other items include small geodes and numerous shale chips	0.10
5	—Blocky, gray-brown shale	1.10
4	—Hard, thin-bedded argillaceous limestone; gray-blue; weathers creamy white; lower $\frac{1}{4}''$–$\frac{1}{2}''$ contains pelecypods, conchostracans, and insect wings, upper $1''$ contains large hopper crystals; in some places clams and conchostracans are found on weathered surfaces and are also scattered throughout the rock; lower portion immediately below clam-conchostracan zone is irregular and laminated; bed stands out as a distinct weathering unit. Sampled for fossils as follows (Measurements are given in mm. below top of bed no. 4):	

5 mm.: *I.* (*Eu.*) *harveyi* A & B
7 mm.: *I.* (*Eu.*) *harveyi* B
8 mm.: *I.* (*Eu.*) *harveyi* A & B
9 mm.: *Productae dunbaris*
10 mm.: *Productae dunbaris*, *Myalina meeki* D
11 mm.: *Productae dunbaris*
12 mm.: *I.* (*Eu.*) *harveyi* A & B
12.8 mm.: *I.* (*Eu.*) *harveyi* A & B
15 mm.: *I.* (*Eu.*) *harveyi* A
22 mm.: Conglomeratic layer, very thin and restricted, *Productae dunbaris*
35 mm.: *I.* (*Eu.*) *harveyi* B
40 mm.: *I.* (*Eu.*) *harveyi* B, insect wing
43 mm.: *I.* (*Eu.*) *harveyi* B, reptilian scale
46 mm.: Insect wing, xiphosuran genus and species, *Stronglylocephalus charactis*, n. gen., n. sp. (Pl. 98, fig. 2)

Bed No.	*Feet*
52 mm.: hopper crystal; remnant of thin conglomeratic zone including shale chips 56 mm.: Insect wing 80 mm.: *I.* (*Eu.*) *harveyi* A & B 82 mm.: *I.* (*Eu.*) *harveyi* A & B 84 mm.: *I.* (*Eu.*) *harveyi* A & B	
Hopper crystals throughout upper 30 mm.; also pseudomorphs of halite	0.28
3—Brown-yellow plastic shale grading down to blue-black and black shales	5.20
2—Black gypsiferous shale grading down to massive gypsum beds; several non-persistent gypsiferous shale ledges stand out in this unit	5.25
1—Massive pink and black-white gypsum interbedded with black shale down to creek level. Thickness not taken since base of bed could not be determined	——
Total Measured Thickness	24.06

Outcrop Belt D

Locality No.: *Sedgwick I*, Sedgwick County, Kans. S line, SE, SW, sec. 17 T. 25 S., R. 2 E. (0.75 miles S. of Furley and 1.8 miles west of Hwy 835).

Bed No.	*Feet*
7—Series of thin-bedded, platy, argillaceous limestones; interbedded with some thicker beds of shale; no visible fossils; series comprises about four thin limestone units of maximum thickness of 0.5 feet	6.50
6—Blue-gray argillaceous limestone containing rotten plant debris and carbonized wood zone; stands out as distinct hard unit; weathered surface pock-marked	0.21
5—Green-drab plastic shale; thin carbonized zone near top	1.65
4—Light gray argillaceous limestone; peculiar small pointed mound-like markings that suggest desiccation; medium-to-thin bedded and platy	0.45
3—Gray-green blue blocky and plastic shales	2.80
2—Buff-gray, blue-white-gray argillaceous limestone; weathers white. Middle one-third contained: *Isaura* (*Euestheria*) *harveyi* A & B, *Rugoplanorboidella segdwickii* (Pl. 97, fig. 3), reptilian fragments, poorly preserved punctate ostracod valve. Lower one-third: insect wing, plant fibers, carbonized wood fragment and limonitic seed coat	0.19
1—Gray-green-drab, hard and waxy, very blocky-to-laminated shales; extremely fossiliferous. Arbitrarily divided into three units for sampling: Upper ⅓: *I.* (*Eu.*) *harveyi* A & B; *I.* (*Eu.*) *harveyi harveyi;* reptilian fragments; plant fibers; carbonized seed coat. Middle ⅓: *I.* (*Eu.*) *harveyi* A & B; *I.* (*Eu.*) *harveyi harveyi;* minute isolated discs (reptilian?); seed coat; carbonized plant material; undetermined large pelecypod fragment; plant fibers; *Productae dunbaris.* Lower ⅓: *I.* (*Eu.*) *harveyi* A & B; *Echinestheria annellya;* reptilian scales; *Productae dunbaris*	1.60
Total Measured Thickness	13.40

Locality No.: *Sedgwick III-B*, Sedgwick County, Kans. NE, NW, sec. 13, T. 26 S., R. 1 E. (in creek bed E. of Kechi city limits on Kechi Road, right field going east). S. of this section an excellent exposure in creek bank down to red and blue shales.

Bed No.	*Feet*
5—Platy, gray-green weathering limestone; light gray; fresh surface weathers in sheets	0.25
4—Down to top of joint filling (actually a desiccation crack): gray-drab blue-black shale, blocky and waxy; base of this bed directly overlies a fossiliferous argillaceous limestone joint-filling which cuts across the underlying bed to within 0.1 foot of the next underlying thin hard bed. This joint-filling extends for 3 feet down slope; it has a maximum thickness of 0.15 feet and stands out as a distinct weathering unit surrounded on all sides and in sharp contact with shales of same lithology as described above. Fossils include: abundant reptilian fragments (scales, teeth, etc.), *Isaura* (*Eustheria*) *harveyi* A & B, *Productae dunbaris*	2.62
3—Conchostracan-bearing joint cuts across conchostracan-bearing shales, sampled in thirds as follows: Upper ⅓: *Productae dunbaris*, *I.* (*Eu.*) *harveyi* A & B, *I.* (*Eu.*) *harveyi harveyi*, reptilian fragments. Middle ⅓: *Productae dunbaris*, *I.* (*Eu.*) *harveyi* A & B, *I.* (*Eu.*) *harveyi harveyi*, reptilian fragments abundant, *Wellingtonia productae* (Pl. 97, fig. 11). Lower ⅓: Possible arthropod axial segment (limonitic and poorly defined), reptilian fragments abundant, insect wing(?), *I.* (*Eu.*) *harveyi* A & B	1.12

Bed No.	*Feet*
2—Hard, pink weathering calcareous argillite; pink color is due to brown-red-to-amber reptilian fragments	0.07
1—Plastic, drab-blue-black shale, massive, blocky, waxy; total thickness not determined; extends down slope several feet. Measurement was not made since base is covered. Some red shales are discernible through the cover. Fossils: algal (?) filament impression; shell impression too poorly preserved for identification	10.0–15.0 (est.)
Total Measured Thickness	14.06–19.06

Locality No.: *Sedgwick II*, Sedgwick County, Kansas. Opposite Wichita University, southeast corner Hillside and 17th Street, City of Wichita.

Due to slump, erosion, and the inability to excavate properly on private property within the city limits, it has not yet been possible to obtain a complete section at this place. From time to time, the writer and various students have collected weathered out fragments and these were found to contain the following fossils: reptilian scales and other reptilian fragments, disseminated carbonized wood, minute ostracods, unidentifiable mollusk fragments, plant impressions, and clam-shrimps assignable to *Isaura* (*Euestheria*) *harveyi* B. (This last item is of interest since previous search failed to reveal the presence of clam-shrimps although they were predicted at this place.) The existence of an Annelly gypsum outcrop a few miles north on Hillside, indicates that the clam-shrimp bed here is some ten to 20 feet above the top of the gypsum. The clam-shrimp horizon at this locality correlates with Sedgwick III-B, bed no. 3, and Sedgwick I, bed no. 2. The undersurface of the piece bearing clam-shrimps had faint salt casts. The thickness of this fragment is 6.0 mm.

SYSTEMATIC DESCRIPTIONS

Order XIPHOSURIDA
Suborder LIMULINA Richter & Richter, 1929
Family EUPROOPIDAE Eller, 1938
PRINGLIA Raymond, 1938

Abdomen triangular, with faint axial furrows, high posterior boss or spine on axis, no raised pleural ridges and probably no marginal spines.

PRINGLIA LEONARDENSIS Tasch, n. sp.
Pl. 98, figs. 4a-b

Description.—Abdomen broadly triangular and convex; axial furrows four in number and clearly but not sharply defined. Most posterior furrow faint and merges with boss. Elevated bulbous posterior boss terminates axis, tapers to blunt node-like spine; boss occupies the portion of the axis as follows: vertically it covers a space equivalent to that of the rest of the furrowed axis, horizontally it extends beyond the axis on either side.

Pleural ridges faintly defined and not raised. Anterior margin of abdomen gently incurved towards middle line drawn through center of axis; slight lip-like projection occurs where incurved right and left anterior margins join; slightly below this margin (i.e., 0.90 mm.) a clearly defined ridge overlies the uppermost axial segment and proceeds to abdominal margins on either side. A similar raised margin continuing somewhat obliquely from the raised anterior ridge, defines the abdominal sides.

Discussion.—Differs from *Pringlia birtwelli* by broad triangular shape, axial expansion into boss instead of constriction before it. The new species shows presence of a raised anterior ridge and projecting lip.

Dimensions.—Length (measured along axis), 4.35 mm.; width (max.), 7.50 mm.; width of axis, 1.75 mm.; width of boss (max.), 2.70 mm.; width of axial furrows uniformly, 0.45 mm.

Material.—Mold and cast of abdominal shield.

Depository.—Univ. of Wichita, Paleontological Collections. Holotype: W.U. 200.

Locality.—Annelly VIII, Bed No. 2, lower portion. Harvey Co., Kans.

Suborder LIMULINA Richter & Richter, 1929
Family unknown
BIFARIUS Tasch, n. gen.
Genotype: *Bifarius comptae.*

Description.—Subovate prosoma lacking genal spines, with incurved anterior margin and partially keeled cardiac lobe bounded by ophthalmic ridge that expands posteriorly.

BIFARIUS COMPTAE Tasch, n. sp.
Pl. 98, figs. 1a-b

Description.—Anterior margin of prosoma incurved along midline where it forms a notch. A narrow line-like elevation (keel)

courses from base of notch along the median line of the cardiac lobe, where it fades out about halfway (i.e., 0.60 mm. from point of incurvature at notch to where it disappears on cardiac lobe). Cardiac lobe bulbous. Eyes, if present, unknown. Ophthalmic ridge touches and conforms to configuration of cardiac lobe and expands posteriorly to right and to left where it cuts posterior margin of prosoma.

A faint granular appearing pattern occurs on the prosoma; the granules are so arranged as to simulate a succession of fine and subdued radial ridges; these ridges form a slightly acute angle with posterior margin of the prosoma and cross it from the ophthalmic ridge on either side; at the incurved portion of the shield these narrow ridge-like markings on the prosoma are parallel to the raised bifurcating line noted above.

Discussion.—Since the new species is quite distinct from all previously described xiphosurans, it doubtless belongs in a new family. The genus is placed under the suborder Limulina tentatively since this includes forms that have keeled cardiac lobes.

Dimensions.—Length (measured through middle of cardiac lobe), 1.35 mm.; width (max.), 1.75 mm.; width of prosoma beyond cardiac lobe, 0.60 mm.; width of prosoma beyond cardiac lobe at the notch, 0.15 mm.; width of cardiac lobe (max.), 0.90 mm.; expansion of ophthalmic ridge where it cuts posterior border of shield, 1.35 mm.

Material.—Mold and cast of dorsal shield.

Depository.—W.U. Paleontological Collections, Holotype, W.U. 201.

Locality.—Annelly I-A, Bed No. 6, Harvey County, Kans.

Suborder unknown
Family unknown
STRONGYLOCEPHALUS Tasch, n. gen.
Genotype: *S. charactis.*

Subround dorsal shield lacking eyes and ophthalmic ridge and pierced anteriorly by two arcuate slits. Cardiac lobe bears two vertical indentations and its base forms anterior margin of shield.

STRONGYLOCEPHALUS CHARACTIS
Tasch, n. sp.
Pl. 98, fig. 2

Description.—Prosoma faintly granular, broadly round to oval, anterior margin slightly indented along midline of cardiac lobe and between arcuate slits that pierce margin; arcuate slits fade out on prosoma to right and left and anterior to cardiac lobe; area defined by slits slightly raised. Cardiac lobe, large, broadly oval on three sides, culminates anteriorly in a raised constricted area that merges with but is distinct from the slit-bounded area described above. Cardiac lobe bears two well defined vertical indentations which give it a tripartite appearance; basal portion of lobe swollen while median portion between vertical indentations flattened; eyes and ophthalmic ridge not present; curved base of cardiac lobe forms posterior margin of shield.

Discussion.—Distinct from all previously described xiphosurans. Belongs to a separate family and possibly a new suborder.

Dimensions.—Length (through centerline of cardiac lobe), 1.35 mm.; width (max.), 1.65 mm.; width (max.), cardiac lobe, 1.05 mm.; width (max.), beyond cardiac lobe, 0.75 mm.; width of rise marked off by arcuate slits, 0.15 mm.; width between vertical slits on cardiac lobe (max. from base), 0.60 mm.; (minimum, anteriorly), 0.45 mm.

Material.—A single dorsal shield.

Depository.—Univ. of Wichita, Paleontological Collections, Holotype: W.U. 202.

Locality.—Annelly I-A, Bed No. 4, 1.5' below top, Harvey Co., Kans.

Suborder unknown
Family unknown
HYPATOCEPHALA Tasch, n. gen.
Genotype: *Hypatocephala rugosa.*

Oval dorsal shield bearing cardiac lobe well removed from the posterior margin; ophthalmic ridge does not meet in front of the cardiac lobe but terminates on either side of it and defines the convex portion of the shield. Prosomal area above this portion is flat.

HYPATOCEPHALA RUGOSA Tasch, n. sp.
Pl. 98, fig. 3

Description.—Oval dorsal shield as long as wide, with cardiac lobe slightly raised, clearly defined, partly flattened and wrinkled, and beginning slightly below anterior margin of shield, expanding slightly over 1.0 mm. in length of 3.0 mm.

Cardiac lobe has no distinct or regular furrows but rather is fairly crenulated and terminates in a narrow ring.

Ophthalmic ridge expressed not as a distinct rise on prosoma but by the swollen area below and flat area above it where it joins cardiac lobe on either side.

Discussion.—Cardiac lobe resembles a trilobite glabella and the ophthalmic ridge a palpebral lobe of a trilobite, but the differences from a trilobite are striking—for example, the high position on the shield of the cardiac lobe.

No previously described xiphosuran comes close to this new species, which may ultimately be accommodated in a new family and suborder when more material becomes available.

Dimensions.—Length (through cardiac lobe), 5.10 mm.; length of cardiac lobe, 2.85 mm.; width (max.), 5.10 mm.; distance from anterior margin of shield to anterior border of cardiac lobe, 1.35 mm.; base of cardiac lobe width, 2.40 mm.; smallest width (anterior) cardiac lobe, 1.35 mm.; distance from anterior margin of shield to where ophthalmic ridge joins cardiac lobe, 1.80 mm.; thickness of basal protruding ring set off from posterior termination of cardiac lobe, 0.15 mm.

Material.—A single dorsal shield.

Depository.—W.U. Paleontological Collections. Holotype: W.U. 203.

Locality.—Elmo V, top slope. Dickinson Co., Kans. (Note: Details on Dickinson Co. sections will be published in an ensuing paper. This species is included here under new xiphosuran genera and species for completeness).

Phyllum MOLLUSCA
PATELLOIDEA Tasch, n. gen.
Type species: *P. limnensis.*

Minute, fresh water patelliform gastropod. Apex overhangs anterior end; upper surface convex.

PATELLOIDEA LIMNENSIS Tasch, n. sp.
Pl. 97, fig. 4a-b

Description.—Strongly expressed concentric ornamentation weathers in the fashion of overhanging shingles, giving shell a rugose appearance. Last few growth lines crowded together.

Dimensions.—Length (max.), 3.90 mm.; width (max.), 3.30 mm.; height (max.), 1.50 mm.

Discussion.—This shell is so minute, it was almost overlooked. While several high and low spired gastropods have been found with fossil clam-shrimps in the beds studied, this is the only specimen of a patelliform type found in the dozens of outcrops examined through four counties.

Depository.—W.U. Paleontological Collections. Holotype: W.U. 300.

Locality.—Jester Creek II, slab 1, undersurface (bed 9a^{v}), Harvey Co., Kans.

PERMOPLANORBOIDEA Tasch, n. gen.
Type species: *P. primus.*

Small, fresh water, dextral shell, carinated above.

PERMOPLANORBOIDEA PRIMUS
Tasch, n. sp.
Pl. 97, fig. 1

Description.—Internal mold, one and one-quarter whorls; nature of aperture and lip unknown.

Dimensions.—Width, 2.00 mm.; length, 3.00 mm.

Depository.—W.U. Paleontological Collections. Holotype: W.U. 301.

Locality.—Jester Creek II, top surface of Bed No. 20. Harvey County, Kans.

RUGOPLANORBOIDELLA Tasch, n. gen.
Type species: *R. sedgwickii.*

Small, fresh water sinistral shells with rugose whorls.

RUGOPLANORBOIDELLA SEDGWICKII
Tasch, n. sp.
Pl. 97, fig. 3

Description.—Internal mold, isolated fragments of whorls resemble corals; outer whorl expanded over earlier ones; inner whorls and aperture unknown.

Dimensions.—Height, 1.35 mm.; length, 1.27 mm.

Discussion.—Numerous detached fragments of whorls are readily identifiable on the basis of characteristic rugosity.

Depository.—W.U. Paleontological Collections. Holotype: W.U. 302.

Locality.—Annelly I-A, Bed No. 14, Harvey Co., Kans.; Sedgwick I, Bed No. 2, Sedgwick Co., Kans.

Gastropod genus and species undet. No. 1
Pl. 97, fig. 2

Description.—Small, sinistral, spiral fresh water gastropod. Poor material does not permit description of this species. Like the other mollusks in the Leonardian fresh water beds, it is probably a new genus and species.

Depository.—W.U. Paleontological Collections. W.U. 303.

Locality.—Annelly I-A, Bed No. 14, Annelly III-A, Bed No. 9. Harvey County, Kans.

STAGNESTESTA Tasch, n. gen.

Type species: *S. solitaria.*

Fresh water pelecypod with smooth subtrapezoidal valves.

STAGNESTESTA SOLITARIA
Tasch, n. sp.
Pl. 97, fig. 5

Internal mold of left valve; dorsal margin and steep anterior side join at midpoint of terminal beak forming angle of 106 degrees; posterior side joins dorsal margin with obliquity in beak direction forming an angle of 133 degrees; postero-ventral margin sharply curved in contrast to antero-ventral margin.

Numerous concentric growth lines, shell smooth, no other visible ornamentation.

Dimensions.—Length, 5.4 mm.; height (max.), 4.5 mm., height (min.), 3.3 mm.

Discussion.—This distinctive genus was found at only one locality and on one horizon. It appears to represent an example of speciation in a small pond situation.

Depository.—W.U. Paleontological Collections. Holotype: W.U. 304.

Locality.—Jester Creek VII, Bed No. 3b. Harvey Co., Kans.

MYALINA MEEKI Dunbar
Pl. 97, fig. 6

Dunbar (1924) figured only line drawings, hence a photograph is given here. This species represents a brackish water form. Where it occurs in the Leonardian beds studied, it indicates proximity to the sea of a pond-dotted swamp area.

This species has been found with fresh water faunas including fossil clam-shrimps and mollusks at several localities. It is of interest that there are two distinct times of influx of this species as shown at locality Annelly I-A. Here it occurs on two horizons separated by some eleven feet of intervening beds.

Depository.—W.U. Paleontological Collections. W.U. 305.

Locality.—Annelly I-A, Bed No. 4 and Bed No. 14, Annelly III-A, Bed No. 5, Harvey Co., Kans., as well as at Dickinson Co. localities.

ROSTROTORTUS Tasch, n. gen.

Type species: *R. dissimilis.*

Fresh water pelecypod with subovate valves and looped umbo.

ROSTROTORTUS DISSIMILIS
Tasch, n. sp.
Pl. 97, fig. 7

Description.—Internal mold of right valve, subovate; umbo raised; beak appears looped, anterior and posterior margins join umbonal region obliquely; about fourteen concentric growth lines, no detectable ornamentation.

Dimensions.—Length, 4.0 mm.; height, 2.8 mm.

Discussion.—The distinctive feature of this pelecypod is the looped beak. Due to the raised umbo it may be viewed from above where it is clearly defined. The upper portion of the umbo is crushed and the writer wondered if this or erosion might explain the looped effect. There are two arguments against such explanations: (1) the loop is created by a distinct narrow slit, almost a sinus, in the beak seen from above, and is quite unlike the rest of the crushed umbonal area, (2) the looped effect was found on two specimens collected at different localities. The likelihood of such a recurrence based on non-genetic causes is very slight.

Depository.—W.U. PaleontologicalCollections. Holotype: W.U. 306.

Locality.—Jester Creek XI, Bed No. 20, Annelly VIII, Bed No. 2, Harvey Co., Kans.

Pelecypod genus and species undet. no. 1
Pl. 97 fig. 8

Description.—Internal mold of left valve almost circular in shape; umbo raised, swollen anteriorly, beak overhangs hingeline; valve smooth, growth lines weakly defined; other ornamentation not detectable.

Dimensions.—Length, 5.0 mm.; height, 6.0 mm.

Discussion.—Due to the poor preservation of this solitary specimen, no detailed description is possible at this time. However, a glance at Pl. 98 will show that it is unlike the other pelecypods described in this paper. Since it was found only at one locality, it provides further evidence of speciation in a small pond situation.

Depository.—W.U. Paleontological Collections. W.U. 307.

Locality.—Jester Creek XI, Bed No. 20. Harvey Co., Kans.

PRODUCTAE Tasch, n. gen.

Type species: *Productae dunbaris.*

Pelecypod with elongate-elliptical valves, and beak recessed from anterior margin.

PRODUCTAE DUNBARIS Tasch, n. sp.
Pl. 97, fig. 9

Description.—Internal mold of left valve; numerous concentric growth lines; molds of both valves often occur together. Probably a brackish water form (cf. *Myalina meeki* D.).

Dimensions.—Width, 7.0 mm.; height, 3.0 mm.

Discussion.—This species is named for Professor Carl O. Dunbar who first noted its presence as "minute" or "dwarfed" pelecypods (Dunbar, 1924) but did not figure or describe them. It is a widespread species and tends to form coquina-like accumulations. They are found on surfaces bearing clam-shrimps and reptile fragments.

The distinctive feature is the horizontally elongate-elliptical configuration of the valves. The specimens at hand are small but not dwarfed.

Depository.—W.U. Paleontological Collections. Holotype: W.U. 308.

Locality.—Sedgwick I, Bed No. 1, middle and lower thirds; Sedgwick III-B, Bed No. 3, middle third, Sedgwick Co., Kans.; Annelly I-A, Bed Nos. 4 and 14; Annelly I-D, Bed No. 2; Annelly I-C, Bed Nos. 4 and 5; Annelly III-A, Bed No. 7; Annelly IV, Bed No. 2, Harvey Co., Kans., and Dickinson Co. localities.

ELLIPTOIDEA Tasch, n. gen.

Type species: *E. vulgaris.*

Small pelecypod with vertically elongate subelliptical valves.

ELLIPTOIDEA VULGARIS
Tasch, n. sp.
Pl. 97, fig. 10

Description.—Posterior margin sharply rounded to join straight hingeline; umbo anterior and below hingeline; numerous growth lines trace subovate outline about umbo; growth lines bear minute bead-like markings that stand out in relief.

Dimensions.—Width, 8.0 mm., height, 2.0 mm.

Depository.—W.U. Paleontological Collections. Holotype: W.U. 309.

Locality.—Annelly I-C, Bed No. 5; Annelly I-A, Bed No. 14, Harvey Co., Kans.

WELLINGTONIA Tasch, n. gen.

Type species: *W. producta*, n. sp.

Slender, vertically elongate spiral and dextral gastropod.

WELLINGTONIA PRODUCTA
Tasch, n. sp.
Pl. 97, fig. 11

Description.—Five-to-six whorls. Several internal molds or external impressions of this species are at hand. Details of aperture and ornamentation unknown.

Dimensions.—Height, 20.0 mm.; width (max.), 5.0 mm.

Depository.—W.U. Paleontological Collections. Holotype: W.U. 310.

Locality.—Sedgwick III-B, Bed No. 3, middle third, Sedgwick Co., Kans.; Annelly I-A, Bed No. 4, Annelly I-C, Bed No. 5, Annelly I-D, Bed No. 2, Annelly III-A, Bed No. 5, Harvey Co., Kans.

ADDENDUM

Since this paper was written, two clam-shrimp horizons older than C_1 have been found in Sedgwick County. These two horizons, C_0(younger) and C_{00}(older) occur in the Annelly gypsum. They are respectively 3.5 feet and 6.0 feet below the top of the Annelly gypsum and hence from some 13 to 17 feet below the C_1 horizon at locality Annelly I-A. Details of this section will be given in a subsequent part of this series. It will suffice here to indicate that the upper of these two units occurs in a gray-black waxy shale and the lower in a laminated argillaceous limestone, and in each case these beds

are overlain and underlain by massive gypsum beds.

REFERENCES

DELLWIG, L. F., 1953, Hopper crystals of halite in the Salina of Michigan: Am. Mineralogist, v. 38, nos. 7–8, p. 730–731.

DUNBAR, C. O., 1924, Kansas Permian insects, Pt. 1: Am. Jour. Sci., 5th Ser., v. VII, no. 39, p. 175–208.

HENDERSON, J., 1935, Fossil non-marine Mollusca of North America: Geol. Soc. America, Special Paper No. 3, 268 p. (Permian, p. 23).

KELLEY, R. W., 1956, Natality factors of selected species of Phyllopoda: Doctoral dissertation, Univ. Missouri, p. 1–150.

PENNAK, R. W., 1953, Fresh water invertebrates of the United States, New York: Ronald Press, 726 p.

RAYMOND, P. E., 1924, Late Paleozoic xiphosurans: Bull. Mus. Comp. Zoology (Harvard), v. 94, no. 10, p. 475–508, 2 pls.

SELLARDS, E. H., 1908, Cockroaches of the Kansas Coal Measures and the Kansas Permian: Univ. Geol. Survey, Kans., v. 9, p. 501–541, pls. 70–83.

——, 1909. The Permian flora of Kansas: Univ. Geol. Survey, Kans., v. 9, p. 434–467.

STØRMER, L., 1955, "Merostomata" *in* Treatise on Invertebrate Paleontology, Pt. P, Arthropoda 2, p. 10–23.

TASCH, P., 1958, Permian conchostracan-bearing beds of Kansas, Pt. 1: Jester Creek Section—Fauna and Paleoecology: Jour. Paleontology, v. 32, p. 525–540, 1 pl.

——, 1960, Paleoecological observations on the Wellington salt (Hutchinson Mbr.): Trans. Kansas Acad. Sci., v. 63, p. 24–30.

TILLYARD, R. J., 1937, Kansas Permian insects, Pt. 20: The Cockroaches or order Blattaria: Pts. 1 and 2, Am. Jour. Sci., 5th ser., v. 34, no. 201, p. 169–200; no. 202, p. 249–276.

JOURNAL OF PALEONTOLOGY, V. 35, NO. 4, P. 866–879, 3 TEXT-FIGS., JULY, 1961

PALEONTOLOGICAL NOTES

CORRELATION WITH GREAT BRITAIN OF GLEN DEAN CRINOID FAUNA (CHESTER, MISSISSIPPIAN) FROM ILLINOIS BASIN

ALAN S. HOROWITZ AND T. G. PERRY
Ohio Oil Company, Littleton, Colorado; Indiana University, Bloomington, Indiana

A study has been made of crinoids from Indiana and Kentucky from the Glen Dean Limestone, which lies at the top of the middle Chester (Homberg Group) in the Illinois Basin. Because Wright (1950–60) has completed a review of British Carboniferous crinoids, particularly those of Scotland, a general comparison of Glen Dean crinoids with those from British Carboniferous rocks can be made. Crinoid calices, on which much of the following discussion is based, currently do not provide a faunal zonation as critical as that shown by goniatites.

The following twenty-three species are found in the Glen Dean Limestone in Indiana and northern Kentucky:

Agassizocrinus conicus Owen & Shumard
A. laevis (Roemer)
Aphelecrinus bayensis (Meek & Worthen)
A. oweni Kirk
A. randolphensis (Worthen)
Eupachycrinus boydii Meek & Worthen
E. germanus Miller
E. spartarius Miller
Hypselocrinus n. sp.
Onychocrinus pulaskiensis Miller & Gurley
Phacelocrinus longidactylus (McChesney)
Phanocrinus compactus Sutton & Winkler
P. formosus (Worthen)
P. parvaramus Sutton & Winkler
Pterotocrinus acutus Wetherby
P. bifurcatus Wetherby
P. depressus Lyon & Casseday
P. spatulatus Wetherby
P. vannus Sutton
Tholocrinus spinosus (Wood)
Zeacrinites doverensis (Miller & Gurley)
Z. trapeziatus (Sutton & Hagan)
Z. wortheni (Hall)

The writers are not aware of any crinoid species that are found both in the Illinois Basin and in Great Britain. However, the Glen Dean species *Aphelecrinus oweni* Kirk is very similar to *A. dilatatus* Wright. Both species are characterized by flaring radial plates in the dorsal cup. Wright (1954, p. 171) originally referred *Onychocrinus liddelensis* to the Glen Dean species O. *pulaskiensis*, but the British species lacks spinose primibrachials, although the two species are similar in other respects.

The marine Carboniferous in Europe long has been zoned by means of goniatites. In Great Britain an additional zonation of the Lower Carboniferous has been based on corals. In the United States goniatites are virtually unknown from the Chester of the Illinois Basin, the type area of the Chester. Although individual species of solitary rugose corals are abundant in Chester marine sequences, colonial forms are not common and the Chester has not yet been zoned on the basis of corals. Generally the type Chester is correlated with rocks in the Midcontinent region, especially the Batesville, Fayetteville, and Pitkin Formations of Arkansas and the upper Caney and Goddard Shales of Oklahoma. Because rocks of Chester age in Arkansas and Oklahoma contain goniatites and other molluscan faunas similar to those in Great Britain, they can be compared with European sequences. The accumulated evidence of this indirect correlation of the Chester in the Illinois Basin with Europe by way of Oklahoma and Arkansas suggests that the Viséan-Namurian boundary (P_2-E_1) probably lies somewhere within the middle Chester (Homberg Group) in the type area of the Chester in the Illinois Basin.

Table I indicates the ten crinoid genera found in the Glen Dean Limestone in Indiana and northern Kentucky according to our study. The numbers of species for each genus is compared with the number of species recorded in North America from Chester, pre-Chester, and post-Chester beds. These data are based primarily on the compilation by Bassler & Moodey (1943). A

TABLE 1. DISTRIBUTION OF SPECIES IN TEN GENERA IN DIFFERENT STRATIGRAPHIC INTERVALS OF NORTH AMERICA AND GREAT BRITAIN

Genera	Number of Species							
	North America				Great Britain			
	Glen Dean	below Chester	Chester	above Chester	Coral Zone 3	below Viséan	Viséan	above Viséan
Agassizocrinus	2	0	11	3	–	–	–	–
Aphelecrinus	3	2	9	0	4	0	5	0
Eupachycrinus	3	2	11	0	0	0	2	0
Hypselocrinus	1 (n sp.)	11	1	3	0	0	2	0
Onychocrinus	1	7	3	0	2	2	2	0
Phacelocrinus	1	2	8	0	0	2	0	0
Phanocrinus	3	0	14	0	6	0	7	0
Pterotocrinus	5	0	27	0	–	–	–	–
Tholocrinus	1	0	3	0	–	–	–	–
Zeacrinites	3	5	18	2	1	0	2	0

similar comparison is made with the pre-Viséan, Viséan, and post-Viséan beds of Great Britain based on the work of Wright (1950–60). As pointed out above, the Chester is not strictly comparable to the Viséan because in North America late Chester rocks probably are Namurian. In addition, the lower Viséan includes beds that would be placed in the Meramec in North America. The table does show the similarity between the occurrence of Chester crinoid faunas and those of the Viséan as exemplified by the Glen Dean genera of this study. Moore (1948, p. 388, fig. 9) reached the same conclusions for the Meramec-Chester crinoid faunas of North America.

A more striking comparison occurs when the Chester is compared with Hill's Coral Zone 3 of Scotland from which Wright obtained many of his Scottish crinoids. *Aphelecrinus* and *Phanocrinus*, which are restricted to the Chester in North America or which reach a peak of species abundance in the Chester, are almost restricted to Coral Zone 3 in Scotland. This suggests that the crinoids of Coral Zone 3, which includes the Lower Limestone Group of Scotland, are essentially equivalent to the Chester in North America. Coral Zone 3 in Scotland contains the Viséan-Namurian boundary as does the Chester in North America. The placement of the Viséan-Namurian boundary above the Glen Dean as suggested by Weller *et al.* (1948) or below the Glen Dean as suggested by the work of Gordon (1953) and Elias (1952; 1956) cannot be resolved on the basis of our crinoid data.

This manuscript is published by permission of the State Geologist, Indiana Geological Survey.

REFERENCES

BASSLER, R. S. & MOODEY, M. W., 1943, Bibliographic and faunal index of Paleozoic pelmatozoan echinoderms: Geol. Soc. America Special Papers No. 45, vi+734 p.

ELIAS, M. K., 1952, New data on Dinantian-Namurian equivalents in America: Troisème Congrès pour l'Advancement des Études de Stratigraphie et de Géologie du Carbonifère, Heerlen, v. 1, p. 189–201.

——, 1956, Upper Mississippian and Lower Pennsylvanian formations of southcentral Oklahoma, *in* Petroleum Geology of Southern

Oklahoma, v. 1, p. 56–134, 6 pls., Tulsa, Okla., Am. Assoc. Petrol. Geologists.
GORDON, MACKENZIE, JR., 1953, Carboniferous goniatite zones of Arkansas and their correlation (abs.): Geol. Soc. America Bull., v. 64, p. 1427–1428.
MOORE, R. C., 1948, Paleontological features of Mississippian rocks in North America and Europe: Jour. Geology, v. 56, p. 373–402.
WELLER, MARVIN, ET AL., 1948, Correlation of the Mississippian formations of North America: Geol. Soc. America Bull., v. 59, p. 91–196, 2 pls.
WRIGHT, JAMES, 1950–1960, A monograph on the British Carboniferous Crinoidea: Paleontographical Soc., 2 v., xxx+347 p. 83 pls.

THE TYPE OF *PENTREMITES* SAY

ROBERT O. FAY
Oklahoma Geological Survey, Norman

The type specimen of *Pentremites godoni* (DeFrance), the type species for the genus *Pentremites* Say, has been destroyed. The holotype is the specimen figured by Parkinson (1808, pl. 13, figs. 36, 37), who obtained it from Dr. Woodhouse of Philadelphia. Parkinson (p. 235) mentioned that the specimen came from Kentucky "where similar bodies are frequently found of a larger size." He used the name "Kentucky Asterial Fossil" in the table of contents and termed it "An asterial fossil from America; probably of the nature of the encrinus" on the plate. The date November 1, 1807 appears at the bottom of the plate; thus it is evident that Dr. Woodhouse sent the specimens before that date.

James Parkinson died at Hoxton on December 21, 1824, and his widow was bequeathed his entire collection, according to Critchley (1955, p. 134). The collection was auctioned in 1827 (Sherborn, 1940), and Mr. Featherstonhaugh purchased the "fine series of silicified zoophytes" according to Mantell (1850, p. 14). The zoophytes, which included almost all the fossils, were taken to the United States where "some years afterwards [the collection] was destroyed by a fire which consumed the museum in which it was placed." Thus the holotype of *Pentremites godoni* was destroyed in this fire. Mantell reprinted Parkinson's plates and added the comment on the blastoid: "from the cherty Carboniferous limestone of Kentucky. Some of the Kentucky limestone beds swarm with the remains of these zoophytes."

Before selecting a neotype, a diligent search for other possible types was undertaken, with hopes of finding a precise stratigraphic and geographic placement of the type. This has resulted in the finding of new literature not listed in standard bibliographic works.

Samuel Latham Mitchill (1764–1831), M.D., a professor at the University of New York and Congressman in 1808, is considered to be the "Father of American Geology" by Hall (1934). Mitchill founded the *Medical Repository* in 1797, a New York City journal in which he published extensively. One of the first published works on a blastoid (perhaps preceeding Parkinson's work) is contained in this journal by Mitchill (1808): "*Uncommon Petrifactions, from Georgia and Kentucky.*

"Two rare extraneous fossils have been discovered, one in Georgia and the other in Kentucky. They have both been presented to Dr. Mitchill. The former . . . is an *echinus*, or *sea-urchin*. . . .

"The latter of these rarities is from Kentucky. One of them has been received several years ago from Dr. S. Brown, of Lexington, now of Orleans; and several others since from Professor Woodhouse. They have a remote resemblance to a small acorn. At the larger end is a small projection resembling a broken footstalk. At the smaller extremity are six indentations, or orifices, which may be imagined to be the decayed pistils or stigmata of a former blossom. And on the sides are figured fine sharp-pointed surfaces, having a similitude to the quinque-partite calyx of a plant. It may be doubted whether this is of animal or vegetable origin. It also may be reasonably supposed to be a species of *echinus*. / Both the specimens are siliceous and insoluble in acids. / Figures of them are annexed of the natural sizes. A, the upper side of the Georgia echinus. B and C, upper and lower views of the Kentucky echinus."

The reference to the sea urchin (figure A) is omitted above because this specimen is a true echinoid and has no bearing on the problem. The specimens (figures B,C) shown by Mitchill are of *Pentremites godoni* and are different views from those of Parkinson who published the same year. It is clear that the first person to collect a blastoid must have been Dr. Brown who preceded Dr. Woodhouse in sending specimens to Mitchill.

Samuel Brown, M.D. (1769–1830), moved to Lexington, Kentucky, from Philadelphia in 1797 to join his brother and practice medicine. While in Lexington he travelled extensively and took interest in nitre deposits in caves because of rumors of impending war with the British (War of 1812) and the possible need for an inland supply of gun powder. In 1805 and 1806 he visited many caves in Kentucky and regularly sent specimens to the American Philosophical Society in Philadelphia. The records of the Proceedings of that society, reprinted by Lesley (1885), show that Brown sent specimens on May 3, November 1, and December 20, 1805, and it is highly probable that these collections contained blastoids. Brown also submitted a manuscript on the cave deposits on February 7, 1806, later published in the Transactions (1809). It is quite probable that Dr. Woodhouse sent some of these specimens to Mitchill and Parkinson. In 1806 Dr. Brown left Lexington for Natchez and New Orleans, later residing in Huntsville, Alabama. He returned to Lexington in 1819, joined the medical school of Transylvania University, and returned to Huntsville in 1825, where he died in 1830 (Dictionary American Biography, vol. 3, p. 152). It seems natural to credit the discovery of blastoids to Dr. Samuel Brown in 1805. It is also evident that Brown probably had no blastoids in his collection after 1806, having sent the specimens before leaving Lexington.

James Woodhouse, M.D., (1770–1809) was a professor at the University of Pennsylvania. Apparently he published nothing about the specimens in his collection and soon after his death the collection was willed to the museum of the American Philosophical Society (June 23, 1809). This museum was known as Peale's Museum or the Philadelphia Museum (1784–1850), separate from the museum of the Philadelphia Academy of Natural Sciences which later became the official museum of the Society (see Faxon, 1915; Colton, 1909; Meisel, 1926). Peale's Museum, a place of amusement, contained the collections of Thomas Jefferson, Major Stephen Long, Lewis & Clark, and others. In 1850 the natural history collections were purchased for about $6,000 by P. T. Barnum and Moses Kimball. Up to that time many specimens were traded to foreign and domestic museums, and after that date the collections were divided into three parts. A large portion remained at Barnum's Philadelphia Museum, which was completely destroyed by fire in 1851. A second portion was sent to Barnum's American Museum in New York, where it was destroyed by fire in 1865. The third portion (mostly birds) was sent to Boston where it became part of the museum of the Boston Society of Natural History (until 1902). The fossils of this museum were acquired by Harvard University, but it is improbable that fossils were ever sent out of Philadelphia to Boston. The *Pentremites godoni* in the collections at Harvard were acquired much later, some by purchase. It is evident that the specimens of *Pentremites godoni* in the original Woodhouse collection have been destroyed.

The last remaining specimens that could be considered as neotypes are those that were in the Mitchill collection in New York City. These specimens were donated by Mitchill (1826, p. 40) to the New York Lyceum of Natural History with the note: "Thirteen specimens, some compressed, others perfectly shaped; a few fractured, the greater part entire; certain of them naked, the rest with their matrix adhering. From Kentucky. They had been received by the donor before the year 1810; and had been particularly noticed as exceedingly singular relics, in Mitchill and Miller's Medical Repository, vol. xi, p. 415. Is the pentremite which is laterally considered as having given rise to the family blastoidea. Of the several species belonging to the genus pentremite, the Kentucky fossil, is the pentremites florealis.—Brown—(Acad. Nat. Sciences, vol. iv, p. 295.)" The reference to Brown is not understood because the author of the article is Say. The entire collection of the Lyceum was destroyed by fire on May 21,

1866, according to Meisel (1926, p. 238), and thus the *Pentremites godoni* in the Mitchill collection were destroyed.

It is possible that J. M. L. DeFrance (1819), who was the first to use a binomial zoological designation for a blastoid species by using the name *encrina Godonii* for Parkinson's figures, may have had some specimens in his collection at the University of Caen, France. Unfortunately the DeFrance collection was destroyed in July 1944 at the battle of Caen in World War II (Claude Pareyn, personal communication, August 2, 1960).

Thomas Say (1820) first used the name *Pentremite* for the specimen figured by Parkinson but failed to name a species and overlooked DeFrance's article. Von Schlotheim (1820, p. 339) applied the name *Encrinites florealis* to the specimen figured by Parkinson, and Say (1825, p. 295) changed the name to *Pentremite florealis* both overlooking the work of DeFrance. Etheridge & Carpenter (1886, p. 157) designated *P. florealis* as the type of *Pentremites*, with reference to Say (1825), thus establishing the type as the specimen figured by Parkinson, legally named *encrina Godonii* DeFrance, and now accepted as *Pentremites godoni* as pointed out by Galloway & Kaska (1957, p. 6). Say made no mention of Kentucky blastoids but did examine specimens from Huntsville, Alabama. These original specimens were probably sent to Philadelphia by Dr. Samuel Hazard of Huntsville, and were in Peale's Museum, later destroyed by fire (Weiss & Zeiglen, 1931). The *P. godoni* specimens now in the Philadelphia Academy of Natural Sciences Museum were collected much later, consisting of six specimens of the Wachsmuth & Springer collection and one specimen of the R. Walton collection. These agree well with the characteristics of the type, are silicified, and come from Bowling Green, Kentucky, Kaskaskia group. Of the *Pentremites godoni* specimens that I have seen, the only specimens that appear to be conspecific with the type in size, shape, and preservation are those collected in the Bowling Green area, Kentucky. These are common is some collections and are distinctly different from all other specimens of this species. They are approximately three-fourths of an inch in diameter, are silicified, and are orange-brown in color.

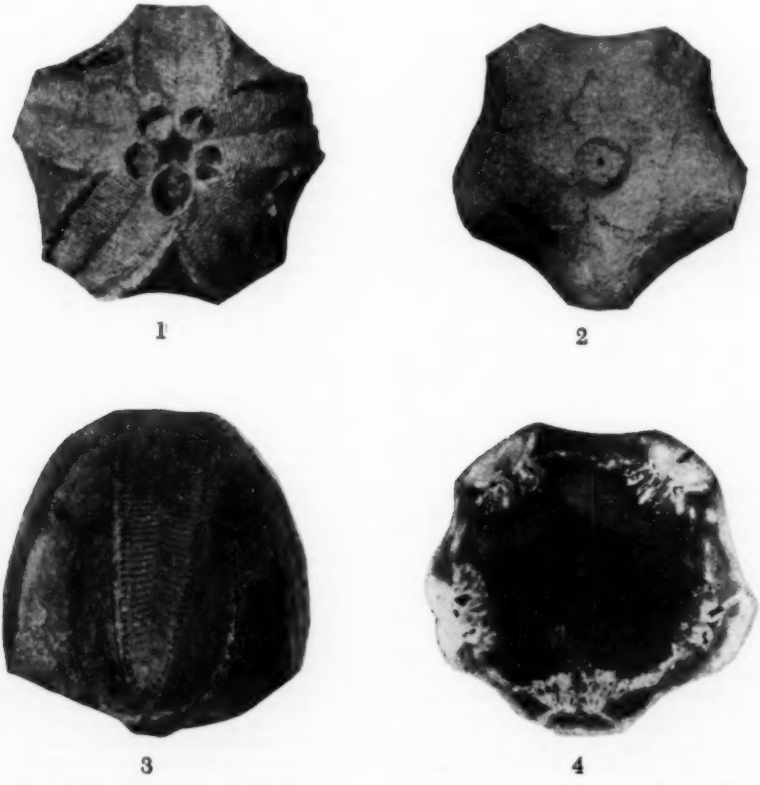
The clue as to where Dr. Brown collected the original specimens of *Pentremites godoni* is to be found in an article by Mitchill (1818, p. 363) in which he stated that "Kentucky abounds with marine relicks. In my possession is an echinus of the family galerite. It was found fossil, and so charged with siliceous particles, as to be insoluble in acids. I received several of them from Dr. Samuel Brown, and Professor Woodhouse. They are detached, and about the size of a middling acorn." He then stated (p. 431, pl. 3, fig. 6) "Petrified echinus from Kentucky. They are said to be frequent in the Great Cavern, near the Green River. *Asterite from Kentucky, petrified.*" The figure given on plate 3 is the same as that of Mitchill (1808, figure B), and from the title of an 1815 article by Mitchill it is evident that the Great Cavern, Green River Cave, and Mammoth Cave are the same. This cave was worked for nitrate before the war of 1812 and it is here assumed that Dr. Brown collected or otherwise obtained the original *Pentremites godoni* specimens from the Mammoth Cave area or Bowling Green region, in 1805. Therefore in selecting a neotype, the specimen should come from this region. I attempted to collect some specimens from the cave area with the park ranger, William Dilley, and learned that *P. godoni* occurs in what would be called the Upper Gasper or Reelsville member of the Paint Creek formation in the cave area, but that well preserved silicified specimens are either uncommon or lacking. The specimens in many collections that are labelled *P. godoni*, Bowling Green, Kentucky, agree in every aspect with the type, and it is here assumed that the original type sent to Parkinson must have come from the Bowling Green area. Of the many collections which I have examined, only one (Harvard) lists the locality as five miles west of Bowling Green. Dr. Erwin Pohl of Horse Cave, who has spent many years in the area, mentioned that *P. godoni*, like the type material, has simply not been found in the Mammoth Cave area, but that *P. pyriformis* is common in the Glen Dean near Brownsville, a few miles away. A detailed account of the rocks of the Chesterian Series of this area is given by McFarlan *et al.* (1955, p. 28). At the

Whitestone Quarry, west of Bowling Green, *Pentremites godoni* is listed as common in the Beaver Bend limestone member of the Paint Creek formation (24 feet thick). It is also found in the overlying Reelsville member (32 feet thick).

The specimens selected to replace the type are part of the Hambach collection at the U. S. National Museum. Hambach labelled the specimens as typical of the type and mentioned that they occur in the ?Upper Gasper, Bowling Green, Kentucky. There are seven specimens in the box with a catalogue number 8437. One of these specimens was selected as neotype and another was cross-sectioned and polished to supplement the neotype with internal characteristics. The new numbers are 139103 for the neoholotype and 139104 for the sectioned specimen.

PENTREMITES GODONI (DeFrance) 1819
Text-fig. 1, figs. 1–4

Calyx 17 mm. high by 15 mm. wide, with vault 15 mm. high and pelvis 2 mm. high, pelvic angle 145 degrees. Deltoids 5, each pierced by a spiracle with large anispiracle piercing anal deltoid, each plate measuring



TEXT-FIG. *1—Pentremites godoni* (DeFrance), neotypes, from ?Upper Gasper, Bowling Green, Kentucky, Hambach collection, U. S. National Museum. All figures ×3.2.
1–3. Oral, aboral, and left posterior ambulacral views of neoholotype, with sutures pencilled, 139103.
4. Cross-section of supplementary neotype (new paratype), with anterior ambulacrum toward bottom of page; view looking aborally, 139104.

8 mm. long by 4 mm. wide. Radials 5, overlapping deltoids, each 10 mm. long by 7 mm. wide. Basals 3, normal, collectively 8 mm. in diameter. Stem round, 2 mm. wide. Ambulacra 16 mm. long by 4 mm. wide, petaloid, with lancet exposed almost its entire width along each ambulacrum. There are 32 side plates in 10 mm. with one pore between each at the marginal edges. The secondary side plate rests on the bevelled abmedial-adoral corner of each primary side plate (medial referring to the line of the main food groove). The oral opening is surrounded by 5 deltoid lips, with deltoid septum covered by side plates, but well exposed in the middle of each spiracle (two on the anal side) internally. Hydrospires 5, normal.

Types.—Neotype (the new type or neoholotype) 139103, U. S. National Museum. Supplementary neotype (new paratype) 139104, U. S. National Museum. From ?Upper Gasper, Bowling Green, Kentucky, Hambach collection. This is here interpreted to mean the equivalent beds of the Paint Creek formation, probably the Beaver Bend limestone, but may include Reelsville member.

REFERENCES

BROWN, SAMUEL, 1809, A description of a cave on Crooked Creek (Madison Co., Ky.), with remarks and observations on nitre and gun powder: Amer. Phil. Soc., Trans., v. 6, p. 235–247 (read February 7, 1806).

COLTON, HAROLD SELLER, 1909, Peale's Museum: Poplar Science Monthly, v. 75, p. 221–238, 1 pl.

CRITCHLEY, MACDONALD, 1955, James Parkinson 1755–1824: London, MacMillan & Co. Ltd., New York, St. Martin's Press, p. 1–268, pls. 1–4.

DEFRANCE, J. M. L., 1819, Dictionnaire des Sciences Naturelles, v. 14, EA-EQE, p. 467.

DICTIONARY OF AMERICAN BIOGRAPHY, 1929–1936: Charles Scribner's Sons, New York, v. 3, p. 152–153, 1929; v. 20, p. 491–492, 1926.

ETHERIDGE, ROBERT & CARPENTER, P. HERBERT, 1886, Catalogue of the Blastoidea in the geological department of the British Museum: London, p. 1–322, pls. 1–20.

FAXON, WALTER, 1915, Relics of Peale's Museum: Cambridge, Mass. (reprinted in Harvard Mus. Comp. Zoöl., Bull., v. 59, no. 3, p. 117–148.

GALLOWAY, J. J. & KASKA, HAROLD V., 1957, Genus *Pentremites* and its species: Geol. Soc. America, Mem. 69, p. 1–104, pls. 1–13, tabs. 1–5.

HALL, COURTNEY ROBERT, 1924, A scientist in the early republic / Samuel Latham Mitchill 1764–1831: Columbia Univ. Press, New York, p. 1–162, 1 pl. Contains much heretofore unpublished information and many references to manuscripts and letters of Mitchill.

LESLEY, J. P., 1885, Early proceedings of the American Philosophical Society from 1744 to 1838: Amer. Phil. Soc., Proc., v. 22, pt. 1, p. 1–875, pls. 1–5 (esp. p. 374, 379, 380, 382, 384, 401, 416).

MCFARLAN, ARTHUR C., SWAN, D. H., WALKER, F. H. & NOSOW, EDMUND, 1955, Some old Chester problems—correlations of lower and middle Chester formations of western Kentucky: Kentucky Geol. Survey, Ser. IX, Bull No. 16, p. 1–37, pls. 1–4.

MANTELL, GIDEON ALGERNON, 1850, A pictorial atlas of fossil remains consisting of coloured illustrations selected from Parkinson's "Organic remains of a former world," and Artis's "Antediluvian phytology:" H. G. Bonn, London, pls. 1–74 (esp. p. 14, 114).

MEISEL, MAX, 1926, A Bibliography of natural history: Premier Publ. Co., New York, vols. 1–3 (Lists the historical development of all learned societies in the United States to 1926, giving disposition of collections, titles and authors of publications of these societies by volume and number, and sources for additional bibliographic studies on each society. This is an excellent reference for paleontologists who wish to locate type material in the United States).

MITCHILL, SAMUEL LATHAM, 1808, Uncommon petrifactions, from Georgia and Kentucky: Medical Repository, v. 11, p. 415–416, figs. A–C (Figures B and C are of *Pentremites godoni*, the first illustrated blastoids in the United States and perhaps the first in the world if they preceeded those of Parkinson, 1808).

——, 1815, Green River, or Mammoth Cave, Henderson County, Ky.: *Ibid.*, v. 17, no. 4, p. 391–393, pl. 1, May 1815 (said to have been written July 5, 1815).

——, 1818, Observations on the geology of North America: *in* M. Cuvier, Essay on the theory of the earth: Kirk & Mercein, New York, p. 363, pl. 8, fig. 6 (Mitchill refigures a specimen from his 1808 work and mentions the Mammoth Cave region on the plate).

——, 1826, Catalogue of the organic remains, which, with other geological and some mineral articles, were presented to the New York Lyceum of Natural History, in August 1826, by their associate, Samuel L. Mitchill: Printed by the Society, New York, 1826, p. 1–40.

PARKINSON, JAMES, 1808, Organic remains of a former world: London, Noraville & Fell, v. 2, p. 235–236, pl. 13 (The illustrated specimen is the original holotype of *Pentremites godoni*).

SAY, THOMAS, 1820, Observations on some species of zoophytes, shells, etc., principally fossil: Am. Jour. Sci., v. 2, no. 2, p. 34–45.

——, 1825, On two new genera and several species of Crinoidea: Philadelphia Acad. Nat. Sci., Jour., Ser. 1, v. 4, p. 289–296.

VON SCHLOTHEIM, ERNST FRIEDRICH, 1820,

Die Petrefactenkunde auf ihrem jetzigen Standpunkte durch die Beschreibung seiner Sammlung versteinerter und fossiler Überreste des Thier- und Pflanzenreichs der Vorwelt erläutert: Gotha, Becker, p. 1–437, pls. 1–15 (p. 339).

SHERBORN, CHARLES DAVIES, 1940, Where is the ———— collection? / An account of the various natural history collections which have come under the notice of the compiler between 1880 and 1939: Cambridge Univ. Press, p. 1–148.

WEISS, HARRY B. & ZIEGLEN, GRACE M., 1931, Thomas Say / Early American Naturalist: Springfield, Ill.—Baltimore, Maryland, p. 1–260, pls. 1–27 (Mentions that Say's specimens were divided between Peale's Museum and the Academy of Natural Sciences Museum).

NOTE ON THE PREPARATION OF SAMPLES FOR DISCOASTERIDS

WILLIAM W. HAY
University of Illinois, Urbana

This technique, used in laboratories of the University of Illinois, is both simple and quick, and offers reasonably clean preparations for study.

(1) A small piece of the sample to be prepared is placed in a porcelain mortar; about five grams is usually sufficient.

(2) Water is added and the sample pulverized by grinding with a porcelain pestle (ordinary tap water is suitable as long as it does not contain coccoliths).

(3) A drop of the muddy suspension is drawn up from the mortar with an eye dropper, and one or two drops of this suspension are placed on a pre-heated cover-glass slip resting on a warm hotplate. Choosing the right moment to draw the suspension into the eye-dropper is the most critical part of the entire operation. After grinding of the sample is finished, the coarse particles settle to the bottom of the mortar within one second. After ten seconds, most of the coccolithophorids have also settled out. The best time for drawing off the samples is a few seconds after grinding, drawing it from the upper part of the suspension. A little experimentation will reveal just how long to wait. A sample drawn off too early will consist chiefly of coarse fragments, one drawn off too late will be too fine to contain coccolithophorids.

(4) The suspension on the hot cover-glass slip is thinned with a few drops of water, and if necessary, spread around the cover-glass with a toothpick. The hotplate should be warm enough that the suspension on the cover-glass slip dries in a few minutes, and cool enough so that the liquid does not boil away and spatter (ca. 150°C).

(5) Beside the cover-glass slip on the hotplate, preheat a glass slide. As the suspension on the cover-glass slip is drying, place two or three drops of CAEDAX thinned with xylol so that it runs freely. This should quickly spread over part of the surface of the glass slide, and bubbles should appear.

(6) As soon as the cover-glass is dry, turn it over and place it on the glass slide. The CAEDAX should run so as to make an even thin layer, filling out all space under the cover-glass. If more CAEDAX is needed it can be added at the edge of the cover-glass slip, and capillary forces will draw it under the cover-glass. The hotplate may be turned higher so as to harden the CAEDAX. Bubbles are expected at this stage but will not affect the finished slide.

After fifteen minutes or so, when the CAEDAX is well hardened and no more bubbles form, the slide is removed from the hotplate, is allowed to cool and is ready for study. The harder the CAEDAX is, the better, for in time the nanofossils tend to drift, especially if the slides are stored upright. If the forms drift, it is usually impossible to relocate any given specimen.

(7) Mortar, pestle, and eye dropper must be rinsed out with acid to destroy any coccoliths remaining and prevent contamination.

This simple method for preparing slides can be done on a mass production basis, with many slides on the hotplate. After a little practice it is easily possible for one person to make 20 to 30 sample slides per hour.

AN OCCURRENCE OF *ARCHIMEDES* IN SOUTHERN NEVADA

N. GARY LANE
University of California, Los Angeles

The genus *Archimedes* is reported here for the first time from the state of Nevada, occurring in rocks judged to be late Mississippian in age. A single screw without attached frond has been found recently in basal beds of the Bird Spring Formation (Indian Springs Member) in Clark County, Nevada. This represents an extension of the known geographic range of the genus in the United States south from northern Utah and west from southeastern Arizona.

The specimen (Univ. Calif., Los Angeles, Dept. Geology No. 32560) was found approximately 80 feet above the Indian Springs-Monte Cristo contact in a coarse-grained ferruginous shaly limestone that weathers dark red. The locality is as follows:

> SE¼ NE¼ Sec. 5, T.19S., R.63E., Dry Lake Quadrangle, Clark County, Nevada. The bed is exposed a few feet below the top of the red-weathering Indian Springs Member on either side of major northwest trending gully that is interrupted upstream by a 100-foot high cliff of dark gray limestone.

The specimen was collected by Terry Cadi, a graduate student in the U.C.L.A. geology department.

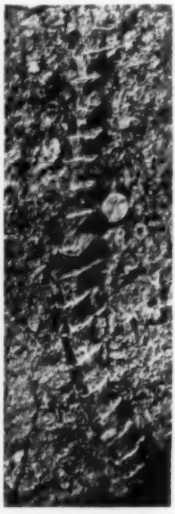
ARCHIMEDES cf. A. SWALLOVANUS Elias, 1957
Text-fig. 1

Archimedes swallovanus ELIAS, 1957, Jour. Paleontology, v. 31, no. 2, p. 415, pl. 47, figs. 11,12.

Description.—The screw consists of 17 volutions and is 68 mm. long. The flange is mechanical or V-shaped, with upper slope more steeply inclined to the axis than lower slope. Average height of volution is 4.0 mm. with a range of about 3.5 to 4.3 mm. The flange diameter averages 7 mm. with a range of 6.2 to 7.3 mm. and shaft diameter is approximately 2 mm. with a range of 1.4 to 2.3 mm. The volution height and shaft and flange diameters remain essentially constant through the 17 preserved volutions, and the range of measurements is at least partly due to indifferent preservation.

The three lower volutions were carefully ground down in the hope of establishing the meshwork formula within the flange. Because of poor preservation no meshwork could be seen in polished or thin sections of the lower volutions. The outer surface of the screw is preserved as a dark brown iron oxide coating and the interior is largely recrystallized.

Discussion.—The dimensions of the screw of *Archimedes pseudoswallovanus* given by Elias (1957, p. 415) are 3½ to 5 mm. for height of volution with an average of 4½ mm., flange diameter of 7 mm., and shaft diameter of 2 mm. These measurements agree closely with the dimensions cited above. In shape and size of screw *A. pseudoswallovanus* is similar to *A. swallovanus* Hall and the two species are distinguished by different kinds of fronds. Because the frond is not known for the specimen under discussion it can be only tentatively assigned to *A. pseudoswallovanus*, although it



TEXT-FIG. 1—*Archimedes* cf. *A. pseudoswallovanus* Elias. Univ. Calif. Los Angeles Dept. Geology No. 32560. Specimen prior to grinding down lower three volutions. XI.

agrees more closely to published dimensions of that species than it does to the screw dimensions of *A. swallovanus* (Condra & Elias, 1944, p. 132) which commonly has a somewhat thicker shaft.

Fenestella expanses are absent from the bed in which the *Archimedes* was collected. The slab on which the fossil was found was carefully ground and polished on both sides in the hope of finding isolated fragments of *Fenestella* but none was discovered. Other samples of the bed also failed to yield *Fenestella*. The screw is surrounded by isolated fragments of crinoidal material, brachiopod shells, and echinoid spines. It is not part of a clast within the ferruginous limestone matrix. The length of the specimen and fragility of the screw argue against the fossil's having been transported any great distance or reworked from preëxisting beds.

Associated Fauna.—One of the most interesting aspects of finding *Archimedes* in lower Bird Spring rocks is its occurrence within the *Rhipidomella nevadensis* zone. Dott (1955) established this zone in northeast Nevada and considers it to be Springeran in age. He reports *R. nevadensis* to be rare in the upper part of his Tonga Formation and common to abundant in the lower member of the overlying Moleen Formation. The *Archimedes*-bearing bed in the Indian Springs contains abundant *Rhipidomella nevadensis* and seemingly should be correlated with the lower part of the Moleen Formation farther north. In northern Clark County the Indian Springs Member also yields well preserved specimens of *Flexaria* and *Inflatia*, both typically Chesteran productid brachiopods; a large *Schizophoria* quite unlike described lower Pennsylvanian species of the genus that occur in higher beds in the formation; and a large, coarsely plicate new species of *Punctospirifer* that is confined to the *R. nevadensis* zone. This brachiopod fauna of the lower Bird Spring is under study.

If Elias' conclusions are accepted, that the Redoak Hollow fauna of the Springeran is late Mississippian and correlative with the Kinkaid Limestone of the type Chesteran, then the *A.* cf. *A. pseudoswallovanus* reported here provides evidence that the *Rhipidomella nevadensis* zone is Late Chesteran in age and that the Mississippian-Pennsylvanian boundary should be drawn at the top of that zone. Beds immediately overlying the red-weathering Indian Springs Member in northern Clark County contain a typically Morrowan fauna and correlate with lowermost Bird Spring beds in southern Clark County (Goodsprings area; Spring Mountains), where the *Rhipidomella nevadensis* zone is missing and rocks yielding typical Morrowan fossils overlie the Monte Cristo Limestone of lower and middle Mississippian age.

Correlative beds that are Springeran in age include the basal rocks of the Oquirrh Formation in northern Utah, and the uppermost beds of the Great Blue Limestone and Chainman shale. All of these rocks contain *Rhipidomella nevadensis* and seemingly should be regarded as uppermost Chesteran in age.

REFERENCES

Condra, G. E. & Elias, M. K., 1944, Study and revision of *Archimedes* (Hall): Geol. Soc. America Spec. Paper No. 53, ix and 243 p., 41 pls.

Dott, R. H., Jr., 1955, Pennsylvanian stratigraphy of Elko and northern Diamond Ranges, northeastern Nevada: Bull. Amer. Assoc. Petrol. Geol., v. 39, no. 11, p. 2211–2305.

Elias, M. K., 1957, Late Mississippian fauna from the Redoak Hollow Formation of southern Oklahoma, Part I: Jour. Paleontology, v. 31, no. 2, p. 370–427, pls. 39–50.

THE MAGNETIC SEPARATOR AS A TOOL IN MICROPALEONTOLOGY

R. ECKERT, W. W. HAY, G. LORENZ AND P. VOGT
Inst. Geol.-Paleont., University of Basel, Switzerland; University of Illinois, Urbana;
Inst. Geol.-Paleont., University of Basel, and Inst. Mineral.-Petrog.,
University of Basel

One of the most time-consuming operations in routine micropaleontology is the separation of microfossils from the washed residue. When hollow and filled with air, Foraminifera and Ostracoda may often be concentrated with heavy liquids, such as carbon tetrachloride or bromoform. Unfortunately, in most cases it has been necessary to pick out the microfossils by hand. Schmidt (1948) discussed the use of the magnetic separator to concentrate ostracode tests filled with glauconite, and Dow (1960) has discussed the magnetic separation of conodonts from washed residue. A magnetic separator also permits rapid concentration of most calcareous microfossils, even from relatively unfossiliferous residues. The techniques discussed here were worked out using a Franz isodynamic magnetic separator in the laboratories of the Institutes for Geology-Paleontology and Mineralogy-Petrography of the University of Basel, Switzerland.

For a description of the Franz isodynamic magnetic separator, the reader is referred to Dow (1960). In practice, each sample requires individual treatment to obtain the best results. For specific examples and data, see Eckert (1960). A few minutes experimentation usually suffices to determine the proper settings for side slope and the most practical rate of flow. A forward slope of 25° was found to be most efficient for general usage. Best results are obtained when the samples are sized.

The most common impurities in washed residues are marl fragments, glauconite grains, quartz, calcite fragments and bits of larger shells. Marl fragments and glauconite grains are diamagnetic and may be separated from the fraction containing the microfossils using a side slope of 15° to 25° and a current of 1.5 amperes. If these are the only impurities, a pure concentrate of microfossils is shunted to the nonmagnetic side of the chute. Dirty specimens, not suited for study, may be automatically eliminated by using a smaller side slope.

To separate Foraminifera and Ostracoda from quartz, it is necessary to introduce iron into the tests so that they may be drawn to the magnetic side of the chute while the quartz remains on the nonmagnetic side. This is accomplished by treating the sample with a weak (2% to 5%) solution of ferric chloride. The solution is acidic, and in stronger concentrations reacts vigorously with the calcium carbonate of the tests to give off carbon dioxide. The weak solution reacts slowly enough that no appreciable damage occurs when the sample is swirled with the solution for a few seconds. Then the solution is decanted, and the sample washed with water and dried. If very delicate forms are involved, it is advisable to neutralize the solution with a suitable buffer, such as sodium acetate, before pouring it onto the sample. The calcium carbonate fraction of the treated samples has a yellow to orangeish hue due to the deposition of iron on the surface and in the pores. The iron coating, although extremely thin, is sufficient to allow magnetic separation, using a current of 1.6 amperes and a side slope of 3° or less. The fossils are drawn to the magnetic side of the chute, and the quartz grains are shunted to the nonmagnetic side. The thin coating of iron in no way impairs the usefulness of the fossils; indeed, many structural details are brought out more clearly, and the orange stain is well suited to photographic purposes.

Concentration of Foraminifera and Ostracoda from other calcium carbonate particles, such as calcite fragments and bits of larger shells, presents a special problem. Many microfossils can be separated out by simple mechanical means. Since the calcite fragments almost invariably have cleavage faces, while broken shell material is usually platy, they tend to remain at rest on an inclined plane, whereas the Foraminifera and Ostracoda have more rounded surfaces and tend to roll down an inclined plane. A board covered with slick paper and inclined 10° to 20° to the horizontal is very effective

as a mechanical separator, and a few minutes of tapping with a finger produces a concentration of microfossils at the bottom of the board equivalent to many hours picking. For this technique to be successful, it is necessary that quartz grains be eliminated first, for, lacking cleavage faces, they would also collect at the bottom of the board.

These methods open up many previously overlooked deposits to micropaleontological investigation, as it is possible to concentrate the microfossils from larger quantities of seemingly barren residue. The routine job of picking by hand can be almost entirely eliminated. Each sample presents its own special problems, but these can be solved and a concentration effected in a fraction of the time required to pick an equivalent number of microfossils by hand.

REFERENCES

Dow, V. E., 1960, Magnetic separation of conodonts: Jour. Paleontology, v. 34, p. 738–743.

Eckert, R., 1960, Reinigungs- und Anreicherungsversuche an Kleinforaminiferen: Eclogae geol. Helv., v. 43, p. 645–648.

Schmidt, R. A. M., 1948, Magnetic separation of microfossils: Jour. Paleontology, v. 22, p. 530–531.

CONODONTS FROM THE EASTERN FLANK OF THE CENTRAL PART OF THE BIG HORN MOUNTAINS, WYOMING

FRANK L. KOUCKY, NORBERT E. CYGAN, AND FRANK H. T. RHODES
University of Cincinnati, Ohio, University of Illinois, Urbana, and University College, Swansea, Wales

During the past five years the authors have been conducting a study of Paleozoic stratigraphy on the eastern flank of the Big Horn Mountains. Until recently the boundaries of most formations had not been well exposed.

In 1959 the U. S. Forest Service and the Bureau of Public Roads relocated and widened a part of U. S. 14 along the Little Tongue River canyon and in process of doing so exposed all but 20 feet of the section from the Cambrian Gros Ventre formation to the Pennsylvanian Amsden formation. The 20-foot covered portion, extending from the Ordovician Harding sandstone equivalent to the basal Bighorn dolomite, is exposed in the valley of the Little Tongue River below the road.

Samples were collected of each distinctive lithology and contact zone in the entire section. In thick sequences of similar lithology, samples were collected approximately 12 feet apart. The samples collected averaged about one pound. The section consists mainly of thick sequences of limestone and dolomite with occasional shale partings and two sandstone units.

Thin sections were cut from each sample and the remainder was dissolved in acetic acid. The residue was separated with bromoform and the heavy fraction searched for conodonts. Approximately 7,000 conodonts were collected. Larger samples of portions of the section were re-collected during the summer of 1960 and further work is in progress to establish the correlation between these western units and the standard mid-continent sections of the United States.

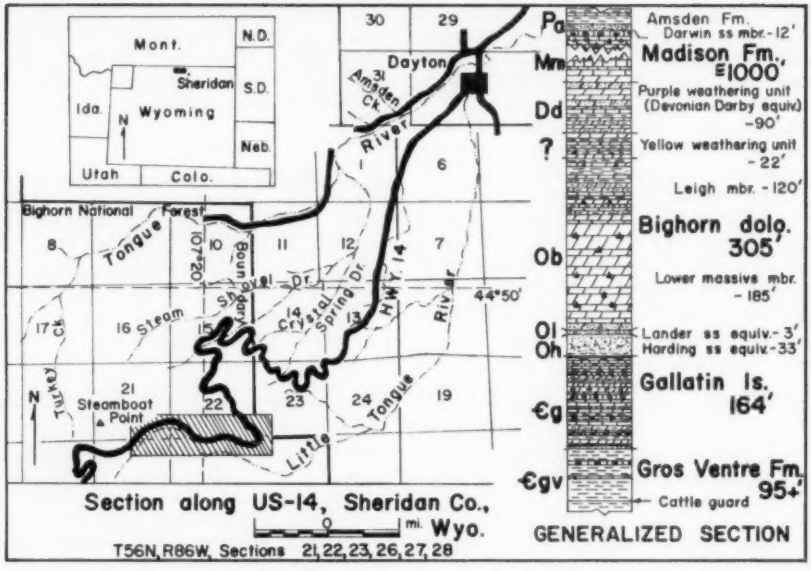
Detailed information about the section and conodont successions will follow in later papers. The portions of the section that yielded fossils are annotated below.

Upper Gros Ventre Formation and Lower Gallatin Limestone.—Several flat-pebble limestone conglomerates were examined and yielded many orbiculoid brachiopods and collections of Cambrian conodonts, including forms resembling *Furnishina* and *Westergaardodina* of Müller 1959.

Upper Gallatin Limestone.—From the limestone near the top of the Gallatin limestone a few conodont fragments were collected that resemble Lower Ordovician forms rather than those of Cambrian age.

Basal Harding Equivalent Sandstone.—From a thin grey sandy shale at the base of the Harding sandstone equivalent was collected a large number of fibrous conodonts, including forms resembling *Chirognathus*, *Microcolodus*, *Stereoconus*, *Mixoconus*, and *Neocoleodus*.

The upper portion of this unit is not exposed along the road but, where exposed in the valley of the Little Tongue River, it



TEXT-FIG. 1—Map showing location (crosshatched area) and generalized section along U. S. Highway 14, Sheridan County, Wyoming.

contains the characteristic fish fragments reported by Amsden and Miller and others.

Lander Sandstone Member of the Bighorn Dolomite and Basal Massive Sandy Dolomite.—The basal sandstone contains a large collection of straight cephalopods and *Receptaculites*. Conodonts collected from this sandstone and the sandy dolomite above include *Panderodus* (most common), *Oistodus*, *Belodina* aff. *B. grandis*, and *Hindeodella*.

Almost all samples of the massive cliff-forming dolomite contained several conodonts of various species but predominantly *Panderodus*.

Upper Thin-Bedded Dolomite Member (Leigh Dolomite).—The upper Bighorn dolomite, above the massive cliff-forming dolomite, is a variable lithology of brightly colored limy shales and shaly limestones. Near the top is a very fossiliferous yellow grey, mottled dolomite with thin interbedded greenish shales containing abundant *Hormotoma* and large ostracods. Conodonts have been found in almost all these units but are more abundant near the top of this sequence. Conodonts collected include several species of *Panderodus* (most common), *Ozarkodina*, *Trichonodella*, *Oistodus*, *Cordylodus*, *Belodina*, *Microcoleodus*, *Pristognathus*, and *Lonchodus*.

Twenty-Three Foot Yellow-Weathering Unit.—A series of thin-bedded shales and limestones that stand out as a distinctive unit is above the greenish shales just described. No conodonts have been collected from this unit, but it was carefully resampled at one-foot intervals during the summer of 1960.

Ninety Foot Bright Purple Shale Unit.—This series is characterized by purplish and reddish thin shales and limestones in the lower part, massive brown and gray limestones containing calcite vugs in the middle and upper sandy limestones. A thin ½-inch bright red sandy shale marks the top of this sequence. Conodonts are abundant in many layers but often the fragments collected have been so rounded as to preclude identification.

Conodonts from the lower part of this sequence include: *Hindeodella*, *Polygnathus glabra*, *Icriodus*, *Lonchodina*, and many

unidentified forms.

No conodonts have been collected from middle massive limestones.

The upper varicolored limestones contain large sand grains and many large pink fish teeth. Conodonts are very abundant, with forms resembling those of the lower Saverton shale of the Mississippi Valley (Lower Upper Devonian). Conodonts of this unit include: *Palmatolepis rugosa, Icriodus, Polylophodonta, Polygnathus, Spathognathodus* (very abundant), *Neoprioniodus, Hindeodella*, and *Lonchodina*.

The thin ½-inch red sandy clay seam at the top of this unit contains an abundant but mixed fauna of Upper Devonian and basal Kinderhook fauna conodont forms. The conodonts here include *Siphonodella sexplicata, Siphonodella quadruplicata, Palmatolepis rugosa, Polylophodonta, Icriodus, Siphonodella duplicata, Neoprioniodus, Ozarkodina*, and numerous species of *Polygnathus*.

Madison Limestone.—The thick sequence of Madison limestone begins above the purplish sequence. These units are more resistant to weathering and form a series of ridges, with oolitic limestones being the most resistant units of the lower part. The basal eight feet of the Madison limestone contain abundant conodonts. The forms found here include: *Siphonodella quadruplicata, S. duplicata, Polygnathus inornata, Spathognathodus*, and *Hindeodella*.

Most of the Madison samples have not yet been dissolved and studied.

Conodonts have been collected from the limestone breccia at the top of the Madison limestone immediately below the Darwin sandstone member of the Amsden formation. This collection compares favorably with Upper Meramec forms of the Mississippi Valley. The collection of conodonts includes: *Trichodonella, Spathognathodus, Apatognathus, Ozarkodina, Elsonella, Hindeodella*, and *Synprioniodina*.

No conodonts were found in the Darwin sandstone or the lower red shales of the Amsden formation, but abundant conodonts were collected from the lowest Amsden limestone. Forms include *Cavusgnathus, Streptognathodus*, and *Idiognathodus*.

Further work by the Forest Department promises to expose the upper part of the Paleozoic section and plans are to complete the sampling of this section.

REFERENCES

Amsden, T. W. & Miller, A. K., 1942, Ordovician conodonts from the Bighorn Mountains of Wyoming: Jour. Paleontology, v. 16, p. 301–306, pl. 41.

Branson, E. B. & Mehl, M. G., 1933, Conodont Studies No. 1: Univ. Missouri Studies, v. 8, p. 1–76.

—— & ——, 1933, Conodont Studies No. 2: The University of Missouri Studies, v. 8, p. 77–170.

—— & ——, 1933, Conodont Studies No. 3: The University of Missouri Studies, v. 8, p. 171–264.

—— & ——, 1933, Conodont Studies No. 4: The University of Missouri Studies, v. 8, p. 265–350.

——, —— & Branson, C. C., 1952, Richmond conodonts of Kentucky and Indiana: Jour. Paleontology, v. 25, p. 1–17.

Collinson, C., Rexroad, C. B. & Scott, A. J., 1959, Abundance and stratigraphic distribution of Devonian and Mississippian conodonts in the Upper Mississippi Valley: Jour. Paleontology, v. 33, p. 692–696.

Downs, H. R. & Youngquist, W., 1950, Conodonts from the Cedar Valley limestone of Iowa: Jour. Paleontology, v. 24, p. 667–672, pl. 87.

Fay, R. O., 1952, Catalogue of Conodonts: Vertebrata, Univ. Kansas Paleont. Contr., Art. 3., p. 1–206.

Klapper, G., 1958. An Upper Devonian conodont fauna from the Darby formation of the Wind River Mountains, Wyoming: Jour. Paleontology, v. 32, p. 1082–1093, pls. 141–142.

Müller, K., 1959, Kambrische Conodonten: Z. deutsch. geol. Ges. (Jg.), Bd. 111, p. 434–485, pls. 11–15.

Rexroad, C. B., 1958, Conodonts from the Glen Dean formation (Chester) of the Illinois Basin: Rept. Inv. 209, Illinois State Geol. Survey.

Scott, A. J. & Collinson, C., 1959, Intraspecific variability in conodonts: *Palmatolepis glabra* Ulrich and Bassler: Jour. Paleontology, v. 33, p. 550–565, pls. 75–76.

Stone, G. L. & Furnish, W. M., 1959, Bighorn conodonts from Wyoming: Jour. Paleontology, v. 33, p. 211–228, pls. 31–32.

Sweet, W. C., 1955, Conodonts from the Harding formation (Middle Ordovician) of Colorado: Jour. Paleontology, v. 29, p. 226–262, pls. 27–29.

Sweet, W. C., Turco, C. A., Warner, Earl & Wilkie, L. C., 1959, The American Upper Ordovician standard. I. Eden conodonts from the Cincinnati region of Ohio and Kentucky: Jour. Paleontology, v. 33, p. 1029–1060, pls. 130–133.

Youngquist, W. & Downs, H. R., 1951, Conodonts from the Lower Mississippian Wassonville dolomite of Iowa: Jour. Paleontology, v. 25, p. 785–792, pl. 111.

JOURNAL OF PALEONTOLOGY, V. 35, NO. 4, P. 880–881, JULY, 1961

NOMENCLATURAL NOTE

AUTHORSHIP OF GASTROPOD GENUS *ASPIDOTHECA*

CURT TEICHERT
U. S. Geological Survey, Denver

Aspidotheca is a genus of the family Bellerophontidae McCoy, 1851, subfamily Pterothecinae Walcott, 1886 (not Wenz, 1938, as stated by Knight *et al.*, 1960, p. I181). In several major treatises I have been cited as the author of this genus, while in fact the person who should be credited with its name is Dahmer, 1936. In the following I wish to put on record a brief summary of the circumstances that have led to this error.

On July 16, 1934, Dr. Georg Dahmer informed me by post card that he was studying a new Lower Devonian fauna from a German locality and that this contained a "peculiar snail," seemingly related to *Pterotheca*. Dr. Dahmer knew that I was at that time working on a paper about *Pterotheca* and related genera. There followed a lively correspondence with Dr. Dahmer on these fossils, and in September 1934 he sent me his specimens for study and comparison with my *Pterotheca* material. He made it clear that he regarded his Devonian form as distinct from *Pterotheca*, and I concurred after having studied his material. During late 1934 there was much further correspondence and exchange of specimens and we at first referred informally to the new Lower Devonian genus, but on December 1, 1934, Dr. Dahmer gave me the name *Aspidotheca* as his final choice. We continued to work on our respective manuscripts, exchanged carbon copies, planned, as far as possible, for simultaneous publication, and both of us included references to the other's paper in his own text. Both papers were completed in manuscript early in 1935.

My paper (Teichert, 1936) appeared in Palaeontologische Zeitschrift, Band 17, Heft 3/4, which bears the publication date: "31.12.1935" (December 31, 1935). I have, however, documentary evidence to show that this issue did not appear at that date, but at some time in 1936. I have a communication from Dr. Dahmer, dated February 1, 1936, in which he thanks me for sending him galley proofs of my paper. He also calls my attention to an error in citation of his own paper, saying that in my bibliography I had given the place of publication of his paper as "Jahrb. Preuss. Geol. Landesanst.," whereas the correct reference was "Abh. Preuss. Geol. Landesanst., N.F., 168." He informed me further that, in order to save time, he had sent this information direct to the editor of the Palaeontologische Zeitschrift. The change was actually made, because the correct reference does appear in the bibliography of my published paper. Thus, my paper was still in press in February, 1936. I do not remember the actual date of its publication, except that it was sometime in 1936.

Dr. Dahmer's paper (Dahmer, 1936) bears the note "Druckauftrag erteilt am 5. März 1936"; that is, it went to press when my own paper was still in proof.

In my paper I introduced the genus *Aspidotheca* in the following manner, after having discussed *Pterotheca* and a related Bohemian genus: "Eine dritte Gattung, welche diesem Formenkreis anzugliedern ist, wird von G. Dahmer (1936) als *Aspidotheca* mit dem Genotyp *A. schrieli* beschrieben." I gave no description of the genus, but discussed its differences from *Pterotheca*. I also described a new species, *Aspidotheca fuchsi*, pointing out differences between it and the genotype, *A. schrieli*. I did not describe *A. schrieli*. It is my considered opinion that I expressed clearly in my article that Dahmer was the author of *Aspidotheca* and its type species, *A. schrieli*, and that I thereby acted in accordance with the requirements of Article 21 of the International Rules of Zoological Nomenclature then in force.

This rule has been only little changed in the revised draft of the Rules, of which the relevant portion is now Art. 22(c) (Bull. Zool. Nomenclature, v. 14, p. 157, 1957).

The first author who attributed the name *Aspidotheca* to me as "Teichert, 1935" was Wenz (1938, p. 111), citing *Aspidotheca fuchsi* Teichert as "*Monotypus*." However, I did not see this publication until several years after the end of the second World War.

In the meantime Knight's "Paleozoic gastropod genotypes" had appeared (Knight, 1941). Knight also attributed the name to me ("Teichert, 1935"), but as genotype he quoted "*Aspidotheca schrieli* Teichert," having type status "by original designation." Knight (1941, p. 46) further stated that "both generic and specific names [of the type species] were originally attributed by courtesy to Dr. G. Dahmer who did not publish them until the following year." I protested against this statement in a letter to J. Brookes Knight, dated December 16, 1941, and Dr. Knight did not dispute my correction in later correspondence. Nevertheless, the identical citation was made in Knight *et al.* (1960, p. I182).

To summarize:

(1) Both Dahmer's paper and mine appeared in 1936. Since both were published in Berlin, Germany, it seems doubtful that records of the actual publication dates still exist.

(2) Regardless of the question which of the papers might have appeared a few months or weeks before the other, the generic name *Aspidotheca* had been chosen by Dahmer and the description of the genus and its type species was by him, not by me. I did not attribute the name to him "by courtesy," but I had his permission to refer to and use his generic name in my paper. I did this in compliance with the provisions of Article 21 of the IRZN which were in force at that time.

(3) It follows that authorship of the genus *Aspidotheca* should be corrected from Teichert, 1935, to Dahmer, 1936. Type species by original definition is *Aspidotheca schrieli*, Dahmer, 1936.

Georg Dahmer died in 1954 (Solle, 1955).

REFERENCES

DAHMER, GEORG, 1936, Die Fauna der obersten Siegener Schichten von der Unkelsmühle bei Eitorf a. d. Sieg: Preuss. Geol. Landesanstalt, Abh., N. F., Heft 168, 36 p., 6 pls.

KNIGHT, J. B., 1941, Paleozoic gastropod genotypes: Geol. Soc. America Spec. Pap. 32, 508 p., 96 pls.

—— *et al.*, 1960, Mollusca 1: Treatise on Invertebrate Paleontology (ed. R. C. Moore), Part I, Geol. Soc. America & Kansas Univ. Press, 351 p.

SOLLE, GERHARD, 1955, Georg Dahmer: Hess. L.-Amt. Bodenforsch. Notizbl., v. 83, p. 337–349, 1 pl.

TEICHERT, CURT, 1936, Über *Pterotheca* Salter und verwandte Bellerophontaceen: Palaeont. Zeitschr., v. 17, p. 167–177.

WALCOTT, C. D., 1886, Second contribution to the studies of the Cambrian faunas of North America: U. S. Geol. Survey Bull. 30, 369 p., 33 pls.

WENZ, W., 1938, Gastropoda, Teil 1: Allgemeiner Teil und Prosobranchia: Handb. Paläozoologie (ed. O. H. Schindewolf), v. 6, VIII+240 p.

JOURNAL OF PALEONTOLOGY, V. 35, NO. 4, P. 882-883, JULY, 1961

REVIEW

ECOLOGY AND DISTRIBUTION OF RECENT FORAMINIFERA, by Fred. B. Phleger, viii and 297 pages, illustrated, 1960. The Johns Hopkins Press; Baltimore. (Price: $7.50)

This welcome book "summarizes the principal work done on the ecology of modern Foraminifera and attempts to integrate the results into a useful system." Phleger notes that most of the studies on Foraminifera in the past have been on their taxonomy and use as stratigraphic markers for geologic correlation, but that Foraminifera are equally of value in problems of oceanography and paleooceanography.

The book is divided into six main sections: I. Introduction and Methods, II. Depth Distribution of Benthonic Foraminifera, III. Marginal Marine Distributions of Benthonic Foraminifera, IV. Distribution Studies of Living Benthonic Foraminifera, V. Studies of Planktonic Foraminifera, and VI. Summary Discussion. Chapter I, Introduction and Methods, discusses the characteristics of modern oceans and the major marine environments, both field and laboratory methods of study. Laboratory methods described are those employed in the Marine Foraminifera Laboratory at Scripps Institution. In the introduction to this chapter Phleger calls attention to the fact that in recent years much specific information about marine distribution and processes has been obtained, but that only part of this available information has been used by geologists in interpreting marine rocks. He further emphasizes that the skeletons of marine organisms are perhaps the best material for determining the environment in which the marine sediments were deposited, because many organisms are specific to a given environment and either resist or do not tolerate radical changes.

Chapter II, Depth Distribution of Benthonic Foraminifera, illustrated by tables, discusses in some detail the depth distribution for the Gulf of Mexico, western Atlantic continental shelf, and Baja California. It also discusses displaced foraminiferal assemblages. The ecological factors of temperature, salinity, food, chemical effects, turbidity, substrate, biological effects, effect of the seasonal layer and pressure affecting the depth distribution of Foraminifera are discussed and examples cited.

The distribution of benthonic Foraminifera in the marginal marine areas is discussed in Chapter III; these marginal areas defined to include marine marshes, estuaries, lagoons and bays, beaches, and the adjacent parts of the continental shelf. Phleger states that in these areas faunal patterns appear to be primarily affected by (1) runoff from land, (2) configuration of the coastline, and by (3) consequent distribution of marine and semi-marine water masses. Lists of important species reported from nearshore areas, open ocean, lagoon, estuary and marsh areas are given. A discussion of marsh forms brings out that these forms are nearly world-wide in distribution, a fact which is difficult to explain as the forms are usually restricted to this environment, whereas marshes do not continuously fringe the coasts. Phleger suggests that these forms were established over a long period when such marshes were more extensive than at present. Thecamoebians are discussed and it is concluded that such forms are abundant in modern estuarine sediments and that these tend to disintegrate when samples dry out. Phleger suggests that these may also occur in similar fossil sediments and might be recovered if proper care were exercised in preparation for study. It seems to the reviewer equally possible that the thecamoebians are overlooked by foraminiferal workers because of their small size. Undoubted fossil forms have been widely recorded in Europe by such protozoologists as Cash, Hopkinson, Wailes, Penard, Hoogenraad, de Groot, and G. and C. Dubois, from Pleistocene marsh and other environments, sporadically through the Tertiary and even as far back as the Mississippian by Vašíček and Růžicka. The chapter concludes with a discussion of coral reef faunas in which lists of characteristic species are given.

Distribution studies of Living Benthonic Foraminifera (Chapter IV) include meth-

ods based on benthonic foraminiferal populations for determining rates of deposition and gives numerous examples from the Gulf of Mexico. Seasonal production of Foraminifera is discussed and areas of high production are noted. In the latter, all are characterized by being areas of high organic production and, hence, high food production. In many areas studied Phleger found the distribution of living specimens to be the same as that of dead tests, suggesting little or no transport of the living specimens. Transportation of living forms, especially young tests, is relatively easy because of their buoyancy and Phleger suggests that this may be one mechanism for the distribution of species.

Chapter V, Studies in Planktonic Foraminifera, is adequately illustrated by graphs and figures. Phleger emphasizes the difficulty of working with planktonics because of the considerable variation within a species and the consequent naming of certain key variants within a population, thus complicating the nomenclature with a variety of names assigned to a single species. There are low-latitude, mid-latitude, and high-latitude planktonic assemblages in modern seas and Phleger contends that this raises problems with long range correlation by means of planktonic Foraminifera. Although fossil planktonic faunas studied by the present reviewer undoubtedly do show some latitude variation, certain species of most faunas have been found to be more widely distributed, and when sufficient material is available world-wide correlations are practicable.

In the Summary Discussion (Chapter V) Phleger suggests that mid and late Tertiary specific and generic assemblages are similar enough to Recent ones to facilitate facies delineation, but that comparison of Cretaceous faunas to modern ones will be difficult, and delineation of facies will be possible only in a general way. "There is insufficient information and understanding now available to permit the preparation of a specific guide for the application of most ecological studies of modern Foraminifera for adequate paleoecologic interpretations of fossil sequences." The frequency of species and the size of populations used by many workers in correlating marine rocks Phleger believes can be used only within a single environment and cannot be used to correlate different environments.

Phleger suggests several research problems in the ecology of modern Foraminifera, among them (1) study of variation in species (and faunas), (2) physiological experimentation to test environmental factors on survival, reproduction, and variation of different species, (3) distribution of planktonic forms from tows, especially the bathymetric distribution, (4) investigation of depth zonation in a variety of areas, (5) examination of trace element composition of foraminiferal tests, (6) investigation of influence of substrate on foraminiferal distribution, (7) detailed population patterns of subspecies, species and larger groups, (8) mechanism of dispersal of benthonic forms, (9) knowledge of nearshore distribution of Foraminifera, and (10) study of Foraminifera in deep sea cores, especially from the southern hemisphere, from high latitudes in all oceans, and from the continental shelf areas.

One hundred ninety-nine references are appended.

For oceanographers, ecologists and paleoecologists, stratigraphers, and workers interested in Foraminifera this work will be of immense interest. It is of especial interest to commercial micropaleontologists evermore concerned with reconstructing fossil environments. Phleger is to be congratulated on writing such a stimulating, interesting, and factual work, which is easy and enjoyable to read.

ALFRED R. LOEBLICH, JR.
California Research Corporation
La Habra, California

JOURNAL OF PALEONTOLOGY, V. 35, NO. 4, P. 884–910, JULY, 1961

SOCIETY RECORDS AND ACTIVITIES

REPORTS AND MINUTES OF THE THIRTY-FIFTH ANNUAL MEETING OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

The thirty-fifth annual meeting of the Society of Economic Paleontologists and Mineralogists was held in the Denver Hilton Hotel, Denver, Colorado, April 24–27, 1961, in conjunction with the annual meeting of The American Association of Petroleum Geologists.

The Society's program consisted of papers on the record of water movements in the development of recent and ancient sediments; papers on paleontology, stratigraphy, and mineralogy; and a special group of papers on the classification of carbonate rocks.

At a joint session on Tuesday morning, April 25, William M. Furnish, President of the S.E.P.M., presented the following address:

THE ROLE OF A SPECIALIST

Mr. Chairman, fellow members of S.E.P.M and A.A.P.G., and guests, in spite of the title, it is my plan to speak about the Society of Economic Paleontologists and Mineralogists, or rather the personnel of this organization. The name is an unwieldy one (incomprehensible to the non-professional), and has been recommended for change. Nevertheless, it seems to be appropriate. If it is possible to interpret the original aims of the S.E.P.M. in a broad sense, it seems to me that it can be regarded as sponsoring expertness or specialization in one phase of petroleum geology. This group was not exclusive, but most had the same interest.

Just thirty-five years ago the initial step was taken by a group of some fifteen paleontologists attending the American Association of Petroleum Geologists meeting in Dallas. Originally designated or regarded as an affiliate of the Association, this Society was conceived to sponsor publication of papers promoting "the science of stratigraphy" through research on microfaunas, as well as larger fossils, and the use of "mineral grains" for correlation; especially as these studies related to petroleum geology. This original purpose is as appropriate today as it was a third of a century ago, and the Society personnel probably have proportionately the same responsibility. It appears, however, that practices and perspectives have altered the concept greatly during the years.

The identity of the Society at this early stage was almost exclusively with micropaleontology. Henry V. Howe presided at the first meeting in March, 1927, when the constitution was adopted. Joseph A. Cushman was first editor; the second editor, Raymond C. Moore, served for nine years. The initial volume of the *Journal of Paleontology* contained a series of studies on the systematic description of small organisms of potential usefulness in oil field stratigraphy, and the techniques employed in such work; a single paper described a method of assigning sand-grain roundness values. Volume I of the *Journal of Sedimentary Petrology* appeared, in 1931, with Moore as editor. The initial number included studies on shapes of particles, bottom samples, accessory minerals, insoluble residues, and clay mineralogy. Bulman outlined the problems of environmental effects on subsurface stratigraphy, and Milner surveyed sedimentary petrology, past and future.

It should be mentioned that twenty to thirty years ago the term "paleontology" was often used in a broad sense as far as the petroleum industry was concerned. Correlation of formations within the domain of practical oil geologists was accomplished by an expert who used "bug tops" for identity. At least in some areas, such as the Gulf Coast, microfossils were the ultimate basis for recognition of beds as they were drilled. At the time this Society originated, cutting samples were accumulated in a most casual fashion, but a few companies initiated sample "libraries." Spot cores were customarily used for identifying the formations lithologically and faunally. During the thirties there were many individuals assigned to documenting well information by plotted

sample logs. The unofficial title of "paleontologist" was assigned indiscriminately, even though the individual may have been unable to differentiate *Guembelina* from *Textularia*, or had little reason to do so. A few standard markers in the interior basin sediments were established on the upper limits of distinctive carbonate, sandstone, or evaporite units in an otherwise monotonous section. In such a case, fossils had less value for identification than intervals and sequences. From a practical standpoint, the degree of knowledge represented by the expert allowed use of fossils in about the same fashion as petrographic detail. The casual student found "near likenesses" to index species throughout similar lithologies. "Hard rock" paleontologists of the Midcontinent unashamedly identified "brachiopod shells and crinoid fragments" instead of key forms. Of course, there were exceptions to these generalizations.

Another stage in the use of expert knowledge for correlation developed in the thirties with widespread availability of electric logs. For a time, the logging engineers (many with geological training) used sample and core logs to establish an acquaintance with local formations and to present a lithologic interpretation. Some experienced geologists viewed these "pictures" with suspicion or skepticism; direct comparisons were difficult because of poor quality samples and few core logs. On an empirical basis, it was nevertheless soon apparent to all who were willing to study and compare E-logs, that correlations between nearby wells in some formations was so obvious that anyone could accomplish it without tedious preparation. This principle was so well conceived that the role of expert could scarcely be applied; drilling and production personnel were able to identify critical points at a glance. Line-depth measurements were so nearly precise, compared with pipe tallies and samples presumably caught "two-per-joint," that datum points were based upon electric-logs exclusively. "Weevils" were tossed a new pile of logs each morning to mark with formation tops and soon became accomplished "slippers." A geologist with a few months' experience correlating logs, or residence in a development area, could identify standard markers across the room or rig floor. The same practice served equally well in the Ordovician and Eocene, with relatively few complications or mysteries. "Amplified" curves provided distinctive patterns in sections lacking apparent lithologic change. Signature patterns and point-for-point correlations were no longer the prerogative of an expert. Under ideal conditions, local correlation became a dreary task as far as hundreds of development wells were concerned. Few stratigraphic problems were encountered or solved as long as emphasis was placed on recognition of "standard datum points."

Nevertheless, the precise measurements and detailed mechanical correlations made it possible to secure an insight into stratigraphy never before possible. For example, an unconformity involving only a few tens of feet of bevel could be analyzed bed-by-bed in three dimensions. Depositional variations in both interval and lithology could be traced and identified with a high degree of certainty. The geologist was provided a view far more comprehensive than could be attained by surface examination under the best circumstances. Without direct comparison, an experienced geologist had fixed in mind a "standard log" which provided all key stratigraphic determinations from memory, with a good insight of structure and facies as well.

Thus an impersonal monster spelled "finis" for a primary function of the ordinary paleontologist and his low-power binocular.

As the use of electric-logs increased, sample loggers ceased to exist in some organizations. There were still problems to be solved by a study of fossils; important wildcats secured well-site determinations or expert laboratory identities of critical markers. This relationship still exists, to a degree, and will at least until continuous logging becomes standard practice. In the meantime, a capable well-sample logger can now qualify as an expert or specialist, if he is able to make positive stratigraphic identifications beyond structural control and equate the vagaries of drilling operations to precise depth measure.

The field of practical paleontology was stifled but never died. Over a period of years the classic faunas of Cretaceous-Tertiary foraminifera and ostracodes became well

documented. In the Paleozoic, a series of microfaunal groups have come into prominence. The value of fusulines for gross dating and detailed correlation of Pennsylvanian-Permian strata has been demonstrated repeatedly. Conodonts have been found useful, especially in the Devonian. A variety of other groups show promise or can be used in some fashion. The few groups now considered to have little or no correlating value arouse a lingering doubt that further systematic study might prove their usefulness. However, in commercial work there have been many instances of false starts in research assignments which lead to no positive results.

The obstacle of mastering techniques and resolving them to routine is a minor problem compared to familiarization with the complex data. Only a few types of fossils lend themselves to practical paleontology in a fashion whereby anyone but the expert can utilize them effectively. In spite of all the mechanical devices and laboratory aids, direct familiarity through tedious application by a specialist remains a prerequisite. Only such a specialist comprehends the language of description and picture. It takes a "trained eye" to verify that this fossil is really the same as that presented in the literature (more to the point, not the same as that one). Identifications are highly subjective, and the meanings rarely can be simply analyzed. The advantages of a strictly artificial key, set up with reference material alone, seldom prevail over the use of published literature. Published catalogues, range charts, monographs, and treatises have provided great incentive by simplifying this task.

The status of this phase of science as applied to industry or the role played by such a specialist remains one of importance. The optimistic view on the future value of diverse groups outlined by Thalmann at the New York meeting suggests that it is only needed for paleontologists to branch into a variety of fields. Certainly none of the groups has been fully exploited; many have just been discovered. Those best known, the foraminifera, also serve in the best fashion for deciphering paleoecology.

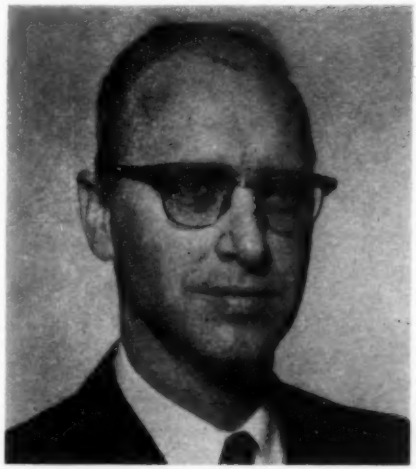
What is the purpose in a study of fossils today? Paleontology as a broad field still has a usefulness in the original sense visualized by the founders of S.E.P.M., but this application is limited compared to the overall growth of the science. The role played by the specialist in this field has become increasingly vital in other respects not so closely allied to "operations." Age determinations and correlation on a regional basis is still a function of faunal determination. Even today, problems are legion. Falsehoods may be perpetrated under the guise of correlation as a result of inadequate knowledge, conflicts of evidence, or subjectivity. In the use of fossils the goal of securing knowledge is always just beyond reach, or subject to additional refinement. Also the shadow of homotaxial relationship is a constant threat to the systematist who carefully lines up stratigraphy with faunal "zones" and "subzones." Perhaps there are cases in which we have exceeded the calibration of our measure (evolutionary development resolved to a study of hard parts), but the history of this science has always been one of taking another closer look. Abandonment of the concept of world-wide synchronous gaps in the record has involved no profound adjustment in paleontology. This field of study will also survive approach to the "new" species concept involving statistical limits, rather than the sanctity of types. Paleontologists will certainly continue to change practices in the future as they have in the past. It appears that the relatively new and scanty absolute dating by geochemistry poses no more of a threat to a study, of, say Paleozoic fossils than it has to archeology, a field enhanced greatly by the new information available. The variety of fields now open for application of faunal studies, such as paleoecology, now has the appearance of being factual, or at least founded on something beyond conjecture. Interpretation of this fund of knowledge to paleoclimatology, by an application of systematic paleontology, or to paleogeography in a strict sense involving changing poles or continental drift is still in an early state. The experience throughout has been that such "academic" information invariably has practical application not recognized in advance. It is fitting that a fair proportion of basic research is now supported by industrial organizations; their staff may

include a good many "oil geologists" who are actually specialists well divorced from oil field operations.

Mineralogy-Petrology, as a field of investigation paralleling that of fossils in correlation, failed to materialize, but does not suffer by comparison as an important field of investigation. Solving regional tectonics by physical measure of sediments alone never approached the role once imagined. At the same time, the use of newer techniques in this regimen has much wider application than could have been visualized thirty-five years ago. There has been so much learned from sources previously unavailable, that today's specialists should be impressed by the complexity and the need for still more basic data. Analysis of quartz detritus, once the main subject of investigation, has been bypassed as "limestone" and "shale" have assumed a spectacular variety of form. These studies have spawned a verbage which must appall the old-time field geologist and well sitter.

Another matter of concern today is the origin of specialists and future source of these individuals. The problem as to whether paleontologists are to be trained primarily as biologists and mineralogists as chemists has been rather thoroughly explored (as an example, J. B. Knight's address of 1947 and the flurry of subsequent comments). The prejudiced opinion of most teachers and practical geologists in America is that individuals in these fields be qualified in all phases of earth science. Irrespective of the merits of such a procedure, there are some redeeming features: high school training has been accelerated as far as basic science and mathematics is concerned and opportunities for intensive research experience in universities have been aided by fellowship funds. A stated principle for university education is: nothing should be taught which can be learned better on the job in a few months. Certainly, this rule has not been the controlling thought in geologic curricula over a period of years. Potentially, advanced university study provides a sifting process, together with disciplines and associations conducive to accomplishment, an atmosphere favorable for the creation of specialists.

Also at the Tuesday morning joint session, the following awards were made: Best paper in the 1959 *Journal of Paleontology*, Best paper in the 1959 *Journal of Sedimentary Petrology*, Best paper at the 1960 Atlantic City Convention, and Recognition of Correspondents.



PAUL BLACKMON

Award for Best Paper in 1959
Journal of Paleontology

The award for the Best Paper in the 1959 *Journal of Paleontology*, consisting of an appropriate scroll, was presented to joint authors—Paul D. Blackmon and Ruth Todd, for their paper entitled, "Mineralogy of Some Foraminifera as Related to Their Classification and Ecology," published in Volume 33, Number 1 (January, 1959).

Paul David Blackmon, now with the U. S. Geological Survey, Branch of Experimental Geochemistry and Mineralogy, Denver, Colorado, was born in Buffalo, New York, on December 11, 1924. After 2½ years in the United States Navy (1944–1946), he attended the University of Buffalo where he received a B.A. degree in February of 1951 and later an M.A. degree from the same institution.

In July of 1952 Mr. Blackmon was employed by the United States Geological Survey where he is at present doing analytical service and research in the field of sedimentary petrology. Mr. Blackmon's

RUTH TODD
Award for Best Paper in 1959
Journal of Paleontology

interests and publications are concentrated on the fields of carbonate geology, clay mineralogy, and glacial geology.

In addition to articles in the *Journal of Paleontology*, Mr. Blackmon has contributed to the *American Journal of Science* and to U. S. Geological Survey publications.

Mr. Blackmon is an associate member of the S.E.P.M., a member of the Geological Society of Washington and the Colorado Scientific Society.

Ruth Todd was born October 22, 1913, in Seattle, Washington. She attended high schools in Seattle and Gering, Nebraska, and received B.S. and M.S. degrees from the University of Washington.

Her entire career, beginning in 1940, has been as a member of the paleontology and stratigraphy branch of the U. S. Geological Survey, during the first 10 years serving as Joseph A. Cushman's assistant at the Cushman Laboratory for Foraminiferal Research in Sharon, Massachusetts, then being transferred to Washington after his death in 1949.

Miss Todd's studies, since 1950, have been on Recent and Tertiary smaller Foraminifera from the Tropical Pacific, especially their ecology and use in correlation. She has published several U. S. Geological Survey Professional Papers and has published, among others, in the *American Journal of Science*, the *Bulletin of American Paleontology*, and the *Journal of Paleontology*.

Miss Todd is a fellow of the Geological Society of America and the Cushman Foundation. She is a member of the Paleontological Society, The American Association of Petroleum Geologists, the Washington Academy of Science, and Sigma Xi.

The award for the Best Paper in the 1959 *Journal of Sedimentary Petrology*, also a scroll, was presented to Robin Gilbert Charles Bathurst, for his paper entitled, "Diagenesis in Mississippian Calcilutites and Pseudobreccias," published in Volume 29, Number 3 (September, 1959).

Born on March 21, 1920, in London, England, Mr. Bathurst is now a teacher of sedimentology and stratigraphy at the University of Liverpool. He attended Aldenham School in Hertfordshire and did undergraduate work at Chelsea Polytechnic Institute. He received a B.Sc. degree in geology from the Royal College of Science, London, in 1948, and a M.Sc. from Cambridge University in 1953. Except for war service Mr. Bathurst has been connected with the University of Liverpool since grad-

R. G. C. BATHURST
Award for Best Paper in 1959
Journal of Sedimentary Petrology

uation. He spent the spring term of 1960 as a visiting professor at the California Institute of Technology, and most of last summer was spent visiting U. S. oil companies and universities, giving lectures or leading in discussions.

Mr. Bathurst's general field of interest is limestone diagenesis and he has published papers on this subject in the *Journal of Geology* as well as the *Journal of Sedimentary Petrology*.

Mr. Bathurst has been an associate member of the S.E.P.M. since 1951 and is also a member of the Geologists' Association of London and the Liverpool Geological Society. In addition, he is a member of the Geological Society of London.

Dr. Wayne A. Pryor was the recipient of the award for the "Best Paper at the Convention." A book by Philip B. King, *Evolution of North America*, was presented to him, for his paper, "Dispersal Centers of Paleozoic and Later Clastics of the Eastern Interior and Adjacent Areas," which was given at the 34th Annual Meeting of the Society in Atlantic City, New Jersey, in 1960. His paper was judged by a committee of five on content, organization, originality, and presentation.

Now a research geologist with the Gulf Research and Development Company in Pittsburgh, Pennsylvania, Mr. Pryor was born in Bellvue, Pennsylvania, on May 6, 1928. He received a B.S. degree in geology from Centenary College in 1952; an M.S. in 1954 from the University of Illinois, and his Ph.D. from Rutgers in 1959.

WAYNE A. PRYOR (left) receiving Award for Best Paper at 1960 Convention.

KOTORA HATAI
Elected S.E.P.M. Correspondent
June 21, 1960

Dr. Pryor has worked for several years for the Illinois Geological Survey doing research in ground water geology and since 1959 has been employed by Gulf, his main interest being sedimentation and clastic mineralogy.

Several of Mr. Pryor's articles have been published in the Illinois State Survey Bulletins. He has also published papers on sedimentation in the *Journal of Sedimentary Petrology* and stratigraphic studies in the *A.A.P.G. Bulletin*.

In addition to S.E.P.M. membership. Dr. Pryor is a member of The American Association of Petroleum Geologists and the Geological Society of America.

The Society's Research Committee nominated and the Council elected two Correspondents—Kotora Hatai and A. Eisenack, in recognition of their outstanding contribution to the field of geology. This award consists of a scroll and the receipt of the

A. EISENACK

Elected S.E.P.M. Correspondent
June 21, 1960

Journal of Sedimentary Petrology for life.

Kotora Hatai, now a professor at Tohoku University, Institute of Geology and Paleontology, Sendai, Japan, was born in Ridley Park, Pennsylvania, on July 21, 1909. He graduated from the above Institution in 1935 and received a Doctor of Science degree from Tohoku Imperial University in 1948.

Dr. Hatai has devoted his professional efforts to the teaching of geology and has done research in marine and coastal geology and paleontology. His publications deal mostly with the Tertiary period and he has done extensive study on brachiopods, otoliths, molluscs, and cirripeds.

Professor Hatai is a member of the Paleontological Association of Japan, the Oceanographic Research Committee of UNESCO, the Malacological Society of Japan, the Mineralogical Society of Japan, the Biogeographical Society of Japan, and has been an associate member of the S.E.P.M. for 12 years.

Professor A. Eisenack was born May 13, 1891, in Altfelde, East Prussia. He studied at the Universities of Jena and Königsberg in Prussia, and graduated from the University of Königsberg in 1931 with a Doctor of Philosophy degree. Since 1951 he has been a professor of geology at the University of Tübingen, Germany.

Dr. Eisenack's main field of interest is micropaleontology, and he has written many scientific articles about graptolites, retiolites, dinoflagellates, and hystrichospheres.

Professor Eisenack is a member of Paläontologischen Gesellschaft and Naturforscher und Arzte.

ANNUAL BUSINESS MEETING

The annual business session of the Society was called to order at 1:30 P.M., Tuesday, April 25, by William M. Furnish, President, who introduced the officers for the new year as follows: President, L. L. Sloss; Vice-President, Kenneth E. Lohman; Secretary-Treasurer, Lloyd C. Pray; Editors of the *Journal of Paleontology*, M. L. Thompson and Charles Collinson; Editor of the *Journal of Sedimentary Petrology*, Lewis M. Cline; and Councilors, Lyman D. Toulmin and Albert L. Kidwell.

It was moved, seconded, and carried that the minutes of the 1960 meeting be approved as published in the June, 1960, *Journal of Sedimentary Petrology* and the July, 1960, *Journal of Paleontology*.

The following reports were not presented at the Business Meeting, but instead they are printed in full below.

Report of the Editors of the Journal of Paleontology (*M. L. Thompson and Charles Collinson*).—Volume 34 (1960) of the *Journal of Paleontology* was published in association with The Paleontological Society and includes, in total, 1228 pages of text and 144 plates, representing 94 papers. The March, July and November issues of the *Journal* were prepared by the Society of Economic Paleontologists and Mineralogists and contain 540 text pages and 64 plates representing increases of 2% and 20%, respectively, over Volume 33. Fourteen of the 64 plates were 300 mesh halftone offset reproductions. The remainder were collotype fulltone reproductions.

Altogether, 39 papers, nine paleontological notes, one nomenclatural note, a review and various Society records and activities were published. Most of the manuscripts originated in midwestern United States with the

S.E.P.M. INCOMING COUNCIL

(For the term ending March, 1962)

Front row, left to right: KENNETH E. LOHMAN, Vice-President; L. L. SLOSS, President.
Second row, left to right: W. M. FURNISH, JR., Past-President; CHARLES COLLINSON, Co-Editor of *Journal of Paleontology;* LLOYD C. PRAY, Secretary-Treasurer.
Back row, left to right: LYMAN D. TOULMIN, Councilor (Paleontology); LEWIS M. CLINE, Editor of *Journal of Sedimentary Petrology;* ALBERT L. KIDWELL, Councilor (Mineralogy).
Not shown in picture: M. L. THOMPSON, Co-Editor of *Journal of Paleontology.*

eastern U. S., Gulf Coast, western U. S., and West Coast following in that order. Manuscripts originating in Australia, Germany, India, Mexico, and U.S.S.R. were also published.

On February 1, 1961, the editors had on hand 43 manuscripts accounting for 1886 manuscript pages and 95 plates. These materials represent a backlog of three and a half issues and a publication delay (for manuscripts received after February 1, 1961) of approximately eighteen months. The average delay in publication for Volume 34 was about ten months.

One of the principal activities of the editors during 1960 was the final preparation of the *Genus-Species, Subject-Author Index to Volumes 1–25* of the *Journal of Paleontology*. On February 1, 1961, page proof for the Subject-Author Index had been read and page-proofing of the Genus-Species portion was in progress. The volume should be ready for distribution before midyear 1961.

The editors are grateful to the Illinois State Geological Survey which provided editorial and financial assistance during the past year. Frances Alsterlund and Romayne

TABLE 1.—*Subject Matter of Manuscripts Published by S.E.P.M. in Vol. 34, Journal of Paleontology*

Subject	Number of Manuscripts
Micropaleontology	18
Macropaleontology	13
Cephalopods	5
Brachiopods	4
Bryozoans	4
Conodonts	3
Foraminifera	3
Paleobotany	3
Techniques	3
Gastropods	2
Ostracods	2
Paleoecology	2
Biostratigraphy	1
Blastoids	1
Branchiopods	1
Calcisphaeres	1
Conchostrachans	1
Graptolites	1
Stromatoporoids	1

Ziroli of the Survey staff deserve special acknowledgment for their efforts in preparing both the *Journal of Paleontology* and the 25-year Index.

The George Banta Company, Inc., likewise deserves special thanks for cooperation and understanding beyond the normal duties of a publisher.

2. *Report of the Editor of the Journal of Sedimentary Petrology (Jack L. Hough).*—The *Journal of Sedimentary Petrology* was published in 1960 as Volume 30, Numbers 1 through 4.

The March number was expanded to 192 pages to accommodate a large backlog of manuscripts. The June and September numbers contained 160 pages each. The last number, in December, was restricted to 128 pages in an attempt to stay within the budget. Meanwhile, the supply of manuscripts had continued to increase, and the delay in publication had grown longer. At the close of the year the backlog of manuscripts was at an all-time high, and all papers were facing a wait of over a year before they could be published. The rate of receipt of new manuscripts was accelerating. The *Journal* is faced with the need, either to turn down many desirable contributions or to expand in size. An expansion in size can only be accomplished if dues and subscription rates are again raised, or if some as yet unknown angel will subsidize publication.

A summary of the contents of the *Journal* is given in the accompanying table. A trend toward publication of a larger number of major papers has been continued during 1960, when the average length of articles increased from 9 pages (in 1959) to 12 pages. The editor has received unsolicited expressions of approval of the publication of the longer papers, from several highly respected members of the Society; it appears, therefore, that a restriction on length of papers would not be a desirable means of providing space for a larger number of papers.

The national origins of the articles, notes, and discussions of Volume 30 were as follows:

United States	43
England	6
Australia	4
Canada	2
New Zealand	1
South Africa	1

Journal of Sedimentary Petrology, Vol. 30, 1960

	Articles		Notes		Discussions		Reviews		S.E.P.M. Data[1] Pages	Advertising[2] Pages	Other[3] Pages	Total Pages
	No.	Pages	No.	Pages	No.	Pages	No.	Pages				
1. (Mar.)	8	153	2	4.5	—	—	4	3.5	23	3	5	192
2. (June)	11	124	2	7	—	—	2	1.5	23	0.5	4	160
3. (Sept.)	13	143	3	5	—	—	1	1	5	1	5	160
4. (Dec.)	11	106	5	7.5	2	2	—	—	—	—	12.5	128
Total	43	526	12	24.0	2	2	7	6	51	4.5	26.5	640

[1] Including membership list (March) and minutes of Annual Meeting (June).
[2] Exclusive of advertisements on covers.
[3] "Other" includes title pages, index, errata, and miscellaneous announcements.

As in the past eleven years, the University of Illinois provided the services of the Editorial staff of the *Journal*. During 1960, Dr. Frederick W. Cropp served as Managing Editor and Mr. Peter Fenner served as editorial assistant.

It was with regret that the Editor withdrew from nomination for re-election to another term of office because of a need to find time for research and other activities. During the twelve years of his service as Editor, the *Journal* has expanded in size from 148 pages to 640 pages per volume (with an increase in number of words per page, meanwhile), and the amount of editorial work involved has increased in proportion.

3. *Report of the Secretary-Treasurer (John Imbrie).*—Income from all sources in 1960, excluding Special Publications, was $8,000 more than in 1959, with an extension in expenses of only $5,000 over 1959. This is due in part to an increase in the subscription rate of the *Journal of Sedimentary Petrology*. The 1960 rate was $11.00 per year, $2.00 over the 1959 rate.

The greatest increase in operating expenses is attributable to printing expenditures, which is more than $3,000 over the 1959 figure. Also included in this amount are increases in salaries, postage, wage taxes, and the expense of the convention. The miscellaneous column in income was augmented with $500 from the Johnson Reprint Corporation for the right to reprint certain volumes of the *Journal of Paleontology;* however, we incurred an additional miscellaneous expense of $345 for attorney fees.

The sale of back numbers increased about $1,000. $700 of this amount represents the sale of two reprinted volumes of the *Journal of Sedimentary Petrology*, which are still in the red about $800.

As of December 31, 1960, our balance in the bank was $45,101.25—an increase over the 1959 figure. The general fund showed a gain of $2,000, but the publication fund showed a drop of $1,000 in round figures. The publication fund is at a dangerously low level. The cost of publishing Barker's *Taxonomic Notes* was $7,450 and has shown a

(*Continued on page 896*)

MEMBERSHIP, MAILING, AND JOURNAL STATISTICS

	Dec. 31, 1960	*Dec. 31, 1959*	*Dec. 31, 1958*
1. S.E.P.M. Membership:			
Active Members	1207	1134	1094
Associates	411	384	351
Correspondents	6	6	6
Honorary Members	7	6	5
	1631	1530	1456
2. *Journal of Paleontology* Mailing List:			
S.E.P.M. Active & Honorary Members	505	509	503
S.E.P.M. Associates	181	173	167
Subscribers	1014	962	912
P.S. Members	741	699	649
	2441	2343	2231
3. *Journal of Sedimentary Petrology* Mailing List:			
S.E.P.M. Active & Honorary Members	836	775	726
S.E.P.M. Associates	277	261	220
S.E.P.M. Correspondents	6	6	6
S.E.P.M. Subscribers	1159	1076	997
	2278	2118	1949
4. Edition of *Journal of Paleontology*	2600	2500	2500
5. Edition of *Journal of Sedimentary Petrology*	2700	2600	2500
6. Number of pages, *Journal of Paleontology*	1228	1139	1170
7. Number of pages, *Jour. Sed. Petrology*	640	632	528
8. Number of plates, *Journal of Paleontology*	144	133	148
9. New members	169	153	125
10. Transfers to active membership	35	32	24
11. Members and associates dropped for non-payment of dues 1/1/61	66	43	65

REPORT OF CERTIFIED PUBLIC ACCOUNTANTS

The Council,
Society of Economic Paleontologists and Mineralogists:

We have examined the accompanying balance sheet of the Society of Economic Paleontologists and Mineralogists at December 31, 1960, and the related statement of income and surplus for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the statements mentioned above present fairly the financial position of the Society of Economic Paleontologists and Mineralogists at December 31, 1960, and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

ARTHUR YOUNG & COMPANY

Tulsa, Oklahoma
January 14, 1961

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
BALANCE SHEET, DECEMBER 31, 1960

ASSETS

	Total	*General Fund*	*Publication Fund*
CURRENT ASSETS:			
Cash	$41,062.71	$32,798.82	$ 8,263.89
Savings account	4,038.56	4,038.56	—
Accounts receivable	391.57	315.57	76.00
Total current assets	45,492.84	37,152.95	8,339.89
PUBLICATIONS:			
Journal of Paleontology:			
Issues prior to 1960—9,742 journals at $0.50 each (1,488 complete volumes)	4,871.00	4,871.00	—
Issues 1 to 6 of 1960—876 journals, at cost	1,793.15	1,793.15	—
Reprints in 1948, Volume 1, 1927—615 volumes, at cost	1,335.57	1,335.57	—
Journal of Sedimentary Petrology:			
Issues prior to 1960—6,628 journals at $0.50 each (1,734 complete volumes)	3,314.00	3,314.00	—
Issues 1 to 4 of 1960—1,207 journals, at cost	1,613.07	1,613.07	—
Reprints in 1960, Volume 19, 1949—341 volumes, at cost	494.96	494.96	—
Reprints in 1960, Volume 21, 1951—353 volumes, at cost	834.09	834.09	—
Special publications, at cost:			
Turbidity Currents, 14 copies	11.97	—	11.97
Recent Marine Sediments, 92 copies	189.84	—	189.84
Finding Ancient Shorelines, 13 copies	22.72	—	22.72
Regional Aspects of Carbonate Deposition, 10 copies	22.32	—	22.32
Journal of Sedimentary Petrology Index, 1,216 copies	702.00	—	702.00
Silica in Sediments, 774 copies	1,708.99	—	1,708.99
Taxonomic Notes—Brady Foraminifera—Challenger Expedition:			
Bound—791 copies	2,967.36	—	2,967.36
Unbound—1,100 copies	3,691.80	—	3,691.80
Total publications	23,572.84	14,255.84	9,317.00
FURNITURE AND FIXTURES (less reserve, $1,857.34)	1.00	1.00	—
DEFERRED CHARGES	5,020.64	794.39	4,226.25
	$74,087.32	$52,204.18	$21,883.14

LIABILITIES AND SURPLUS

CURRENT LIABILITIES:			
Accounts payable	$ 7,622.44	$ 3,716.05	$ 3,906.39
Amount payable to Paleontological Society	3,547.69	3,547.69	—
Total current liabilities	11,170.13	7,263.74	3,906.39
DEFERRED CREDITS:			
Subscriptions to journals—net of portion to be received by Paleontological Society	12,013.41	12,013.41	—
Membership dues for 1961	10,076.00	10,076.00	—
Advance sales, Journal of Paleontology Comprehensive Index	2,103.20	—	2,103.20
Total deferred credits	24,192.61	22,089.41	2,103.20
SURPLUS	38,724.58	22,851.03	15,873.55
	$74,087.32	$52,204.18	$21,883.14

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
STATEMENT OF INCOME AND SURPLUS
YEAR ENDED DECEMBER 31, 1960

	Total	*General Fund*	*Publication Fund*
INCOME:			
Membership dues and subscriptions:			
Journals of Paleontology and Sedimentary Petrology	$ 4,913.00	$ 4,913.00	$ —
Journal of Paleontology	18,222.10	18,222.10	—
Journal of Sedimentary Petrology	17,722.10	17,722.10	—
	40,857.20	40,857.20	—
Sales of special publications:			
Turbidity Currents	43.75	—	43.75
Recent Marine Sediments	717.50	—	717.50
Finding Ancient Shorelines	23.00	—	23.00
Regional Aspects of Carbonate Deposition	294.00	—	294.00
Journal of Sedimentary Petrology Index	137.00	—	137.00
Silica in Sediments	1,012.75	—	1,012.75
Taxonomic Notes—Brady Foraminifera—Challenger Expedition	1,890.15	—	1,890.15
	4,118.15	—	4,118.15
Sales of back numbers:			
Journal of Paleontology	4,809.45	4,809.45	—
Journal of Sedimentary Petrology	2,588.05	2,588.05	—
	7,397.50	7,397.50	—
Sales of plates	528.79	528.79	—
Advertising	539.56	539.56	—
Donation from The American Association of Petroleum Geologists	2,040.00	2,040.00	—
Miscellaneous	917.66	917.66	—
	56,398.86	52,280.71	4,118.15
Less portion of 1960 income accrued to Paleontological Society	3,811.13	3,811.13	—
	52,587.73	48,469.58	4,118.15
COSTS AND EXPENSES:			
Cost of printing:			
Journal of Paleontology	14,586.00	14,586.00	—
Journal of Sedimentary Petrology	13,503.58	13,503.58	—
Journal of Paleontology—Bound Volume 19	609.31	609.31	—
Journal of Paleontology—Bound Volume 21	993.26	993.26	—
Taxonomic Notes—Brady Foraminifera—Challenger Expedition	7,540.72	—	7,540.72
	37,232.87	29,692.15	7,540.72
Expenses:			
Clerical salaries	8,655.00	8,655.00	—
Office supplies	561.75	561.75	—
Postage and express	2,040.27	2,031.10	9.17
Office rent	2,000.00	2,000.00	—
Telephone	53.56	53.56	—
Audit fee	411.73	411.73	—
Payroll taxes	240.12	240.12	—
Miscellaneous	3,274.95	2,946.36	328.59
	17,237.38	16,899.62	337.76
Adjustment for (increase) in inventory of publications	(7,401.48)	(1,797.26)	(5,604.22)
	47,068.77	44,794.51	2,274.26
NET INCOME	5,518.96	3,675.07	1,843.89
SURPLUS AT DECEMBER 31, 1959	33,205.62	19,175.96	14,029.66
SURPLUS AT DECEMBER 31, 1960	$38,724.58	$22,851.03	$15,873.55

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
NOTE TO FINANCIAL STATEMENTS

It is the opinion of counsel that the Society, as a division of The American Association of Petroleum Geologists, is exempt from federal income tax under provisions of Section 501(c) of the Internal Revenue Code, except to the extent of "unrelated business income." The Society, based on the opinion of counsel, has taken the position that none of its income is "unrelated business income" within the provisions of Section 512 of the Internal Revenue Code and therefore no liability has been provided for federal and state income taxes in the financial statements.

(*Continued from page 893*)

return of only $1,890. We must expand the sales of the Barker book and *Journal of Paleontology Index* in order to save the publication fund. During 1960 only 200 copies of *Taxonomic Notes* and not quite 300 copies of the *Index* were sold. Other Special Publications showed a profit with the exception of the *Journal of Sedimentary Petrology Index*, but this red figure is now only a little less than $50.00.

Membership shows an over-all enlargement of 101. This compares with a similar figure of 74 for 1959 and 43 for 1958. As of January 1, 1961, 66 members and associates were dropped for non-payment of dues. On January 1, 1960, only 43 were dropped.

Ten members and associates passed away during 1960.

Calder T. Bressler
Julia Gardner
Paul Herbert, Jr.
J. Brookes Knight
John T. Lonsdale
Hubert Schenck
Clinton R. Stauffer
Emmett P. Tatum
Charles W. Tomlinson
H. J. Weeks

The *Journal of Paleontology* mailing list was expanded by 98, and the *Journal of Sedimentary Petrology* mailing list was enlarged by 160. The preceding year showed corresponding figures of 112 and 169 respectively.

4. *Report of the Research Committee* (*Robert N. Ginsburg, Chairman*).—Membership of this Committee is:

1961	*1962*	*1963*
Heinz A. Lowenstam	R. N. Ginsburg	F. Beales
Franklyn B. Van Houten	H. N. Frenzel	A. T. Cross
A. H. Akers	M. L. Natland	D. J. McLaren
A. C. Munyan	R. W. Schweers	J. M. Schopf
P. W. Reinhart	E. J. Guzman	B. H. Burma

At its meeting in 1959 the committee selected Oceanography as the general topic for the annual symposium in 1961.

The chairman chose to consider for the symposium the record of water movements in the development of Recent and ancient sediments. A two-session program was organized by inviting five major papers.

(1) Sedimentation in Tidal Flat Areas of The Netherlands—L.M.J.U. van Straaten
(2) Genesis of Shoreline Sand Accumulations, Northern Gulf of Mexico—H. A. Bernard, C. F. Major and B. S. Parrott
(3) The Effects of Wind-Driven Water Movement on Sediment Distribution, Gulf of Batabano, Cuba—Albert L. Kidwell
(4) Relations of Reefs to Water Circulation —Joshua I. Tracey, Jr.
(5a) Salinity of Florida Bay—John S. McCallum, Kenneth W. Stockman
(5b) Molluscan Distribution in Florida Bay—W. J. Turney
(5c) Variation in the O^{18}/O^{16} Ratios of Florida Bay Mollusks and their Application to Paleogeographic Studies—R. Michael Lloyd

These authors prepared expanded and illustrated summaries that were circulated to some 100 members of the Society. Several "discussers" were invited to comment briefly on each of the papers.

At the annual meeting in Atlantic City, 1960, the committee selected Pollen as the topic for the annual symposium in 1962. Dr. Aureal Cross was named chairman for 1962.

The committee nominated as correspondents, A. Eisenack and Kotora Hatai. These nominations were approved by the Council.

The chairman attempted to simplify the task of selecting the best papers in the Society's *Journals* by pre-selecting six or more papers. Each of the committee members was asked to choose from this selection, or from the *Journals* themselves, the best papers in each *Journal*. The chairman planned to submit each of the three papers in both *Journals* that received the most votes to selected specialists for further evaluation. Many of the committee members ranked their three choices, and when these votes were tabulated, the paper entitled, "Mineralogy of some Foraminifera as Related to their Classification and Ecology," by Paul D. Blackmon and Ruth Todd in the *Journal of Paleontology* received the most votes. The committee's vote for the best paper in the *Journal of Sedimentary Petrology* was inde-

cisive. The two papers that received the most votes were submitted to three non-committee specialists who were unanimously in favor of the paper entitled, "Diagenesis in Mississippian Calcilutites and Pseudobreccias," by R. G. C. Bathurst.

5. *Report of the Publications Committee (J. L. Wilson, Chairman).*—The Publications Committee of the S.E.P.M. is composed of J. L. Wilson, Chairman, H. A. Ireland, W. Frank Scott, and Weldon W. Rau; Dr. R. N. Ginsburg, as chairman of the Society's Research Committee, is an ex-officio member for 1960–61. Terms of the first two named members expire April, 1961, and terms of Drs. Scott and Rau continue into 1962.

The principal action taken by the Committee was to recommend to A. C. Munyan, last year's Chairman of the Society's Research Committee, that the S.E.P.M. publish as a special volume its 1960 symposium entitled, "Paleontological and Mineralogical Aspects of Polar Wandering and Continental Drift." The symposium in Atlantic City was well attended and elicited very considerable discussion. It was felt that publication of all of the papers on this admittedly controversial and speculative subject would lead to continued discussion in the interest of science.

The committee has also compiled a short list of Russian paleontological papers to recommend to A.G.I. for translation into English.

At the Committee Meeting in Denver, April, 1961, discussion will take place on the advisability of requesting reviewers for *Journal of Paleontology* articles and on the problem of dealing with the large backlog of manuscripts awaiting publication in the *Journals*.

6. *Report on the Earth Sciences Division of the National Research Council (John C. Frye, S.E.P.M. Representative).*—In accordance with its primary responsibility, the Division during the year rendered advisory services to federal agencies through 12 advisory committees; three fellowship committees and four technical committees also were functioning. Two of the advisory committees, the Committee on Seismological Stations and the U. S. National Committee of the International Association for Quaternary Research (INQUA), were formed during the year. A total of 189 scientists took part in the activities of these several committees.

The new Committee on Seismological Stations, chaired by Professor J. T. Wilson, was appointed at the request of the Department of Defense. Its purpose is to encourage fundamental research in seismology, to provide specifications for a network of standardized seismographs, and to suggest criteria for the selection of the recipient stations. As a result of the committee's first meeting, held in San Francisco in April, 1960, a report on the specifications for a world-wide network of seismographs was published.

The other new committee, dealing with Quaternary research, was appointed at the end of June, 1960, under the chairmanship of Dr. G. M. Richmond. The committee is directed to: (1) organize a U. S. delegation to the 1961 INQUA meeting in Poland; (2) determine whether or not there is enough scientific and financial support to extend, during the 1961 meetings, an invitation to hold the 1965 INQUA meetings in the United States; and (3) bring western hemisphere data and viewpoints more forcefully to the attention of European scientists. The first meeting of the committee was held in conjunction with the G.S.A. meeting in Denver in November, 1960.

The other committees of the Division of particular interest to our society include those on Atomic Waste Disposal, Oceanography, Foreign Field Research Program, Fellowships, Clay Minerals, the National Atlas, and AMSOC.

The Committee on Atomic Waste Disposal on land, on which your representative is also serving as a member, held special meetings at the A.E.C. installations at Hanford, Washington, and the National Reactor Testing Station near Idaho Falls, Idaho. Earlier in the year the committee also visited the A.E.C.-sponsored experimental work being conducted in a Kansas salt mine. Research on methods of disposing of radioactive wastes in natural salt beds was first recommended by this committee in 1955. Committee discussions resulting from these three meetings during 1960 were communicated to representatives of the

Commission's Division of Reactor Development.

The Committee on Oceanography is advisory to the A.E.C., C. and G.S., Bureau of Commercial Fisheries, N.S.F., and O.N.R. During the year a number of panels and working groups were active, several conferences were held, and four additional parts of the 12-chapter report, "Oceanography, 1960–1970," were published.

The Foreign Field Research Program Screening Committee during the year selected eight persons from 33 applicants representing 21 institutions of higher learning. The committee on postdoctoral fellowships participates in the screening of applicants in the Fellowship Office of the Academy-Research Council. The number of applicants was about the same as last year and it might be suggested that there should be more competition for these appointments in the Earth Sciences.

The Committee on Clay Minerals held its eighth national conference at the University of Oklahoma, October 12–14, 1959, and its ninth national conference at Purdue University on October 6–8, 1960. An annual volume of papers was prepared as a result of each of these conferences.

The Committee on a National Atlas of the United States has realized that work on the atlas sheets by agencies of the government is proceeding at too slow a rate, and, in order to remedy this, has recommended that the U. S. Geological Survey undertake primary responsibility for the atlas. Atlas sheets currently in print can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., following a recommendation of this committee.

The AMSOC (American Miscellaneous Society Committee) is concerned with planning the ultimate drilling of a hole to the Mohorovicic discontinuity. A preliminary drilling program has been planned and two reports have been issued, "Drilling Thru the Earth's Crust," in 1959, and "Experimental Drilling in Deep Water," in February, 1960. The preliminary drilling program, in addition to furnishing necessary technical and engineering data, is expected to determine whether the second layer of the oceanic crust is sedimentary or igneous.

The annual meeting of the Division was held at the Academy-Research Council Building in Washington, D. C., March 25, 1960, and was attended by the S.E.P.M. representative.

7. *Report of the Joint Committee on Invertebrate Paleontology* (*Raymond C. Moore*). —The most recently completed volume of the *Treatise on Invertebrate Paleontology* series is Part Q on Ostracoda. Copy for pages and illustrations has been delivered to the Meriden Gravure Company in Connecticut for printing. It is anticipated that announcement of availability of bound copies will be mailed from the Geological Society of America headquarters during the spring. This unit contains 442 pages, and thus is comparable to larger previously published volumes. It represents the collaborative work done by 17 authors, and a supplement contains a summary of the recently published USSR volume on this group of fossils.

The next volume to be made ready for Press is Part W which contains sections on conodonts, Problematica, and worms. Typescript and illustrations for this unit have been received and are being processed editorially with expectation of beginning press work in March, 1961.

Other volumes of the *Treatise* nearing readiness for publication are concerned with Foraminifera—at long last being in sight of completion by contributing authors—and the first of three volumes allocated to the Echinodermata. This echinoderm unit will contain general description of the phylum together with morphology and systematic descriptions of primitive pelmatozoans (chiefly cystoids, blastoids, carpoids, edrioasteroids).

Work on yet unfinished volumes is proceeding actively.

8. *Report of SEPM representative on Council of the A.A.A.S.* (*Lloyd G. Henbest*). —Your representative attended the Council meeting of the AAAS December 30 and that of Section E (Geology and Geography). He also attended various scientific sessions. The programs of Sections related to geology treated a number of subjects of interest in petroleum geology and paleontology.

The program of Section E was particularly interesting and well attended. Section E held several joint sessions variously with the

Geological Society of America, Botanical Society of America, Ecological Society of America, American Geophysical Union, and Association of American Geographers. Symposia were held on (a) Palynology; (b) Frontiers in the earth sciences, parts 1 and 2; (c) The Mohole; (d) Selenology; (e) Late Pleistocene of South America; (f) Soviet geography; (g) Economic development and investment in South Africa, and (h) Programming use of natural resources.

Though geologists were prominent among the leaders in organizing the AAAS, they are now so well served by their own national and local societies that Section E has received relatively scant attention from our profession. Under the leadership of Vice-President and Chairman William C. Krumbein, Secretary Frank C. Whitmore, and Program Chairman A. John Haworth, and Past Vice-President Howard A. Myerhoff, Section E has shown new life. Judging by the plans discussed at the Section E committee meeting, December 30, the AAAS meeting in Denver, in December, 1961, will have a program of much interest to SEPM members.

It is recommended that those members of the SEPM who do not belong to the AAAS or subscribe to *Science* take a new look. Since merging with *Scientific Monthly* and undergoing editorial reorganization, *Science* has improved in every respect. Besides having a broadened scientific coverage, *Science* now gives competent attention to national events, issues, and publications that concern scientists. It is also recommended that the SEPM cooperate with the AAAS in every way possible not only for the sake of interdisciplinary exchanges of ideas but in the interest both of improving communication and understanding on all sides of issues affecting scientists and the citizen.

Your representative gained an idea from discussion at the AAAS Council meeting that is recommended for consideration by the members and officers of the SEPM. The increased and improved coverage of scientific events in the newspapers and magazines and response by the public to the AAAS program in New York suggests that the SEPM should consider offering a public lecture as a part of its annual program and as a courtesy to the host town. Communication and publicity in such situations are commonly complicated or inadequate as was shown at New York by the fact that numerous students and adults went to the trouble to inquire how one could attend lectures which were actually programmed for the public. The inquiries indicated (a) increasing public interest in scientific affairs and (b) inadequate publicity. The SEPM membership contains accomplished lecturers and has access to interesting non-member lecturers and programs. It is suggested that communication and publicity might best be obtained by planning well in advance with the local superintendent of schools or principal of the local high school, who would make it an event of the year in high school student and parent activities. It is unnecessary to argue the point that a successful contribution of that kind serves a civic obligation as well as to improve the cultural climate that supports our scientific profession.

9. *Report of Representative on Board of Directors of A.G.I.* (*Samuel P. Ellison*).—Both April and October meetings in 1960 of the A.G.I. Board of Directors were mainly given to a consideration of the reorganization report submitted by the special committee set up for this purpose. After considerable referral back to member societies, a revised version of a new constitution was submitted at the October meeting. The new purposes of the A.G.I. will be to coordinate the activities of its member societies and members. It will promote the advancement of geosciences in the broadest sense, promote fundamental and applied research, promote the improvement of qualifications and attainments of its scientist members, promote high standards in education, professional ethics, and professional performance.

The greatest problem in reorganization is the problem of sustained plans of financing the A.G.I. Solution of this has not yet been resolved.

Throughout the deliberations the S.E.P.M. delegates joined with A.A.P.G. delegates in approval and disapproval of individual items. S.E.P.M. delegates maintained a position that A.G.I. was necessary to the development of the geological profession.

10. *Report of the Permian Basin Section* (*Garner Wilde*).—The sixth annual meeting

of the section will be held April 13–15, 1961, at Midland, Texas. Registration is scheduled to begin the afternoon of April 13th at meeting headquarters, the Scharbauer Hotel. Theme of the technical program is "Sedimentation," and a very fine seminar has been arranged. Mr. Bernold M. Hanson is general chairman.

A field conference which had been held in conjunction with the fifth annual meeting in April, 1960, was offered again in conjunction with the annual meeting of the Southwestern Federation of Geological Societies, October 15, 1960. The field conference, under the very capable leadership of Dr. L. F. Brown, consisted of a detailed inspection of late Virgilian Pennsylvanian rocks of the Brazos River Valley of North Central Texas.

Proposals for joint annual meetings between our section and the Southwestern Federation of Geological Societies have been extended in the hope that conformity to other regional meetings might be achieved. The Permian Basin Section feels, however, that its identity as a regional section must be maintained under such an arrangement.

Officers elected for the 1960-1961 term were: Garner L. Wilde, President; Bernold M. Hanson, 1st Vice-President; Gregory L. Turner, 2nd Vice-President; Cyril J. Perusek, Secretary; Richard D. Jons, Treasurer. Carl Ulvog is immediate past-president. New officers for the 1961–1962 term will be announced at the annual meeting in April.

A series of "Little Lectures" was begun in the Summer in Midland. John Emery Adams spoke on "Ancient Drainage Lines in West Texas," August 29th. Glen L. Evans spoke on "Tertiary Vertebrate Stratigraphy and Paleontology of West Texas," December 6th. A great deal of interest was shown in these very unique lectures, and it is hoped that they might be continued on a year-to-year basis.

As the result of a membership drive held during 1960, the Permian Basin Section has maintained a very substantial membership. Dues notices were recently mailed to over 300 persons, a number of whom reside outside the Permian Basin area.

11. *Report of the Gulf Coast Section (Claude M. Quigley).*—During the past year the membership in this section has grown to 323 members. Already this year we have had several new members and we expect to stay as active as we were under the leadership of President David E. Pope during the last year.

October of 1960 marked the completion of the seventh year of the existence of the Gulf Coast Section of the SEPM. As in previous years, our annual meeting was held in conjunction with the Gulf Coast Association of Geological Societies. This has been a very convenient arrangement for our section. Several of our members have published papers in the "Transactions of the GCAGS."

Two publications were compiled during the past year. One is a directory of the Gulf Coast Micropaleontologists, and the other is the initial set of the type locality descriptions. The purpose of this latter publication is to review and describe all Gulf Coast Cenozoic and Mesozoic type localities and, where necessary, designate and describe alternate or reference localities. This first unit, consisting of 53 pages covering 19 stratigraphic units, was published just before the 1960 annual meeting in Biloxi, Mississippi. This project has been financed by a loan from the GCAGS and it is expected that money received from sales will be used to finance the additional units until the area has been covered.

A field trip is scheduled for May 13, 1961, under the direction of Dick Zingula of Humble Oil and Refining Company.

There is a tentative field trip planned in the spring of 1962 to the Tertiary type localities in southwestern Alabama.

In addition to the annual meeting of the GCS-SEPM, there have been local informal meetings of our members in New Orleans and Houston to promote paleontological and mineralogical ideas in these areas. The officers elected for the 1960–1961 term are: Claude M. Quigley, Jr., President; Harold V. Anderson, Vice President; E. Ann Butler, Secretary; and Edward Marks, Treasurer. Mrs. Sybil Lightfoot has been appointed editor of the GCS-SEPM and will handle the papers submitted to her by our members for publication in this year's "Transactions" of the GCAGS.

12. *Report of Pacific Coast Section (Edwin H. Stinemeyer).*—The Pacific Section has a paid-up membership of 91 as of January 26th. Delinquent notices have been

mailed out to the remaining 92 active members. As of this date, there is $1963.85 in the treasury. The President is Edwin H. Stinemeyer and Secretary-Treasurer is William J. Lewis.

In 1960, National and Pacific Section S.E.P.M. membership awards and subscriptions to both journals were granted to 24 outstanding students from various Pacific Coast colleges and universities. The faculty of the department of geology or paleontology of each school nominated the student to receive the award. A $25.00 certificate for the best paper presented at the November, 1960, Pacific Section meeting was awarded to Dale Wiggins. The certificate was for the purchase of paleontological publications of the winner's choice. The award paper was, "A Mississippian Microspore Assemblage From White Pine County, Nevada."

The monthly Biostratigraphic Seminar sponsored jointly by the Pacific Section of the S.E.P.M. and Bakersfield College is in progress for the seventh year. Eight papers, by distinguished research workers from the West Coast, covering the fields of stratigraphy, paleontology, sedimentation, ecology and oceanography, are being presented. Mr. William R. Barlow is the Chairman. The average attendance at the meeting is approximately fifty.

The S.E.P.M., this year, will sponsor a spring field trip on May 13th. The trip is being planned and will be conducted by a joint committee from the S.E.P.M. and the San Joaquin Geological Society. We are collaborating on this trip because the Geological Society had selected the same general area and time for their trip. After the initial plans were made, the Pacific Section of the A.A.P.G. wished to hold a day of joint technical papers with contributors from the A.A.P.G., S.E.P.M., and S.E.G.; this session would be held on Friday, May 12th. The decision to have this meeting in conjunction with the field trip was brought about as a result of the Pacific Section A.A.P.G.'s election to move the time of the annual joint convention with S.E.P.M. and S.E.G. from the fall to the spring. The purpose of the move was to avoid conflicts with the G.S.A. meetings. It was further decided that on years when the joint national convention was to be held on the Pacific Coast, that no Pacific Section Convention would be held, but that the Pacific Section's efforts would go to assisting the national convention. To keep geologic interest up, however, a field trip would be held during these years. It was felt that the change to a full fledged convention this year was not practical because of the shortening of the preparation time by six months. As General Chairman for the field trip, I have now also assumed the responsibility for the one day joint technical meeting.

The field trip will be on the structure, stratigraphy and paleontology of the southern border of the San Joaquin Valley. The field trip Chairman is Richard Pierce. A Friday evening dinner meeting will be held to present the general geological framework and some of the stratigraphy that will be viewed on the trip. Thomas W. Dibblee, Jr., of the U.S.G.S. at Menlo Park, California, will be one of the principal speakers and field trip leaders. Mr. Robert Nesbit of the A.A.P.G. will be direct Chairman for the Friday, May 12th meeting.

13. *S.E.P.M. President's Report* (*William M. Furnish*).—The Secretary-Treasurer's report and C.P.A. statement indicate that finances of the Society are in relatively satisfactory condition. As previously anticipated, costs relating to the publishing of the *Journal of Sedimentary Petrology* and *Journal of Paleontology* have increased so substantially as to absorb most of the additional income from new members and higher dues. The sale of back numbers and special publications, which has ordinarily contributed a major part of funds available, are well in arrears for 1960. For example, sales of the comprehensive indices for the two *Journals* have not yet balanced printing costs, although that for the *Journal of Sedimentary Petrology* published three years ago is about even, and that for the *Journal of Paleontology* issued only a month ago will likely be in future demand.

Growth of the Society membership has been increasing normally, but greater additions are needed to solve the problem of publication costs. *Journal* editions are still uneconomically low. The near balance which had been maintained with the Paleontological Society's subscription to the

Journal of Paleontology has been upset by a nearly one-fourth increase in that organization's membership. Interest in new S.E.P.M. subscribers continues to favor the *Journal of Sedimentary Petrology*, which has enlarged its coverage greatly and now distributes nearly 2200 copies.

Both of the Society's *Journals* report an increase in the backlog of manuscripts; publication is now delayed longer than a year from receipt. Such a trend justifies an increase in number of pages printed, if their status as leading outlets is to be maintained. No provision has been made for additions in this year's budget, and expenses for the first quarter are under those of a year ago.

Regretfully, Jack L. Hough found it necessary to withdraw from nomination as Editor of the *Journal of Sedimentary Petrology* after serving over ten years in this capacity. Special recognition of his outstanding contribution is acknowledged.

The Research Committee, under Chairman Robert N. Ginsburg, has prepared a symposium for the Denver meetings on the general subject of oceanography. A series of papers dealing with water movement in the development of Recent and ancient sediments is headed by principal guest speaker, L. M. J. U. van Straaten. Next year's plan for a palynology symposium has been complicated by an international conference on this subject at about the same time. Aureal T. Cross, Chairman, will present possible alternatives. Arrangements for publication of last year's symposium on aspects of polar wandering and continental drift are proceeding under the direction of Arthur C. Munyan.

The Permian Basin Section, Pacific Section, and Gulf Coast Section have maintained active programs. Combined memberships now total nearly three-fourths that of active members in the parent Society and Sectional contributions have continued to become of greater importance. Each Section sponsors yearly regional sessions and field conferences. In addition, publications, as well as seminars and lectures or informal meetings, have stressed problems of local interest. It is anticipated that a considerable portion of the responsibility for national meetings will fall on Sections in 1962 and 1963; San Francisco and Houston are host cities.

A Society membership referendum approved support of the American Geological Institute, in principle. Part of the scheduled increase in dues will care for this possible expenditure. In the meantime, reorganization of A.G.I. is pending.

As previously, reports outlining various activities by different committee representatives of the Society will be published in our *Journals*. I hereby express my gratitude to the members who have served as officers, editors, representatives, committeemen and chairmen during the past year. Also, much of the responsibility for providing continuity in Society affairs has rested with the Headquarters' staff. Their capable handling of these details is gratefully acknowledged.

After the President's Report, the following change in the By-Laws, Article I, Section 2, was presented to the Business Meeting for vote by Secretary-Treasurer Imbrie:

"The annual dues of members and associates of the Society who desire only the *Journal of Paleontology* shall be twelve dollars ($12.00). The annual dues of members and associates who desire only the *Journal of Sedimentary Petrology* shall be nine dollars ($9.00). Members and associates may receive both *Journals* by the payment of twenty dollars ($20.00). . . ."

It was moved, seconded, and carried that the dues be increased as proposed.

The meeting was turned over to the incoming president, L. L. Sloss, who called on John C. Osmond to present the *Resolutions of Thanks*.

"The Resolutions Committee, composed of John C. Osmond (chairman), Willard D. Pye, and Thomas W. Amsden, presents the following 'Resolutions of Thanks.'

BE IT RESOLVED THAT in behalf of the Society, we extend an expression of our sincere thanks to the following:

TO LAURENCE L. SLOSS, the technical program chairman, and his very able associates, THEODORE R. WALKER and JOHN CHRONIC, for the preparation and handling of the technical program;

TO R. DANA RUSSELL, S.E.P.M. vice-chairman, for his capable management of

the many details involved in planning an annual convention;

TO ROBERT N. GINSBURG, chairman of the Research Committee, for securing and preparing the Research Symposium on 'Water Movements and Sedimentation';

TO WILLIAM E. HAM, for assembling a group of papers on 'Classification of Carbonate Rocks';

TO LAURENCE BRUNDALL, general chairman, HENRY H. R. SHARKEY, general vice-chairman, ORLO E. CHILDS, A.A.P.G. technical program chairman, and to the chairmen and members of all convention committees for their efforts in behalf of the Convention;

TO RUTH TENER, for providing procedural and communication continuity for an organization with annually changing administrations;

TO THE EXECUTIVE COMMITTEE of the A.A.P.G. for so generously appropriating $2,000 as office rent for the Society Headquarters at Tulsa;

TO OUR EDITORS, M. L. THOMPSON, CHARLES COLLINSON, and JACK L. HOUGH, for maintaining the quality of our *Journals* on a very limited budget;

TO ROBERT H. DOTT, for serving so ably as Business Manager of the Society."

It was moved, seconded, and carried that the above Resolutions be adopted.

It was moved, seconded, and carried that the following Citation, prepared by M. L. Thompson and presented by Charles Collinson, be published in both of our *Journals* as part of the official proceedings:

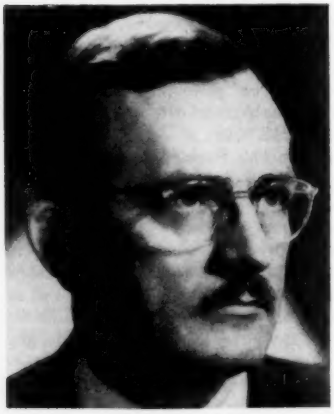
"After 12 years of loyal and distinguished service to the Society, Jack L. Hough has asked to be relieved of his duties as Editor of the *Journal of Sedimentary Petrology*. Only those who have worked at editorial chores can comprehend the magnitude of Dr. Hough's contribution. Thousands of hours of labor are involved as well as serious responsibilities to individual authors, the Society, and the profession in general.

The years of Dr. Hough's tenure have been highly successful ones. For example, when the Society membership was doubling, the *Journal* quadrupled in size and at the same time grew in quality and scope. Today it is the leader in its field, and the Society is justifiably proud. Such status has resulted from the dedicated efforts of its Editor.

It is indeed a pleasure for the Society to publicly acknowledge our indebtedness to Dr. Hough and to express our sincerest appreciation for his long and distinguished service to the Society."

It was moved, seconded, and carried that the meeting be adjourned.

NOMINEES FOR S.E.P.M. PRESIDENT, 1962–1963



JACK L. HOUGH

Professor of Geology, University of Illinois, Urbana, Illinois
Born, March 30, 1909, Chicago, Illinois

Academic Training

University of Chicago, B.S., '32; M.S., '34; Ph.D., '40

Experience

1935–41	Soil Conservation Service, U. S. Department of Agriculture (junior assistant, and associate geologist, engaged in sedimentation studies)
1941–42	Humble Oil & Refining Company (research geologist)
1942–43	U. S. Navy Bureau of Ordnance (civilian consultant)
1943–45	Woods Hole Oceanographic Institution (supervisor of oceanographic research)
1945–46	Standard Oil Development Company (research geologist)
1946–47	Woods Hole Oceanographic Institution (research associate); U. S. Navy Antarctic Expedition (submarine geologist and oceanographer)
1947–	University of Illinois (associate professor, professor)
1954–55	Indian Institute of Technology, Kharagpur (head of Department of Geology and Geophysics)

Publications

Sedimentary petrology, Geology of Great Lakes

(*Continued on page 909*)

M. L. NATLAND

Manager of Production Research, Richfield Oil Corporation, Los Angeles, California
Born, December 4, 1906, Hawley, Minnesota

Academic Training

Pomona College, B.A., '28
University of California at Los Angeles, Ph.D., '52

Experience

1928–	Civil Engineer, Bakersfield
1928–37	Shell Oil Company (micropaleontologist)
1937–	Richfield Oil Corporation (head of micropaleontological department, district geologist, regional geologist, manager of production research)

Publications

Paleoecology, micropaleontology, sedimentary processes

Professional Affiliations

American Association of Petroleum Geologists, member
Geological Society of America, fellow
American Association for the Advancement of Science
Sigma Xi

S.E.P.M. Activity (Member, '38)

1940	Secretary-Treasurer, Pacific Section SEPM
1943	President, Pacific Section SEPM
1948	Member, Nominating Committee
1948, 49	Chairman, Research Committee
1959–61	Member, Research Committee
1961	Presiding Officer, Technical Session on Paleontology and Stratigraphy, Denver Meeting

NOMINEES FOR S.E.P.M. VICE-PRESIDENT, 1962–1963

ROBERT N. GINSBURG

Research Geologist, Shell Development Company, Coral Gables, Florida
Born, April 26, 1925, Wichita Falls, Texas

Academic Training

University of Illinois, B.A., '48
University of Chicago, M.A., '50; Ph.D., '53

Experience

1950–54	University of Miami Marine Laboratory (research assistant)
1954–	Shell Development Company (senior research geologist)

Publications

Sedimentation

Professional Affiliations

American Association of Petroleum Geologists, member
Geological Society of America, fellow
American Association for the Advancement of Science

S.E.P.M. Activity (Member, '56)

1959–62	Member, Research Committee
1960–61	Chairman, Research Committe
1961–	Associate Editor, Journal of Sedimentary Petrology

ALFRED R. LOEBLICH, JR.

Research Geologist (Paleontology and Stratigraphy), California Research Corporation, La Habra, California
Born, August 15, 1914, Birmingham, Alabama

Academic Training

University of Oklahoma, B.S., '37; M.S., '38
University of Chicago, Ph.D., '41

Experience

1940–42	Tulane University (instructor)
1942–46	U. S. Army
1946–57	U. S. National Museum (associate curator of invertebrate paleontology and paleobotany)
1957–	California Research Corporation (senior research paleontologist and research associate)

Publications

Paleontology, stratigraphy

Professional Affiliations

American Association of Petroleum Geologists, member
Geological Society of America, fellow
Society of Systematic Zoologists, fellow
Paleontological Society, member
Cushman Foundation Foraminiferal Research, fellow
Society of Protozoologists, member
Sigma Xi

S.E.P.M. Activity (Associate, '37; Member, '43)

1957–59	Research Committee (Vice-Chairman, '57)
1957	Best Paper Award, Journal of Paleontology
1960	Program Chairman, Pacific Section SEPM

NOMINEES FOR S.E.P.M. SECRETARY-TREASURER
1962–1963

DANIEL J. JONES

Professor of Geology, University of Utah, Salt Lake City, Utah
Born, August 30, 1914, Kansas City, Missouri

Academic Training

University of Oklahoma, B.S., '33; M.S., '35
University of Chicago, Ph.D., '38

Experience

1937–50	Phillips Petroleum Company (research geologist, chief of research department)
1950–	University of Utah (assistant professor, associate professor, professor)

Publications

Micropaleontology, sedimentation

Professional Affiliations

American Association of Petroleum Geologists, member
Geological Society of America, fellow
American Association of University Professors
Sigma Xi

S.E.P.M. Activity (Associate, '35; Member, '51)

LLOYD C. PRAY

Research Geologist, The Ohio Oil Company, Littleton, Colorado
Born, June 25, 1919, Chicago, Illinois

Academic Training

Carleton College, B.A., '41
California Institute of Technology, M.S., '43; Ph.D., '52

Experience

1942	Magnolia Petroleum Company (subsurface geology)
1943–44	U. S. Geological Survey (pegmatite investigations)
1944–46	U. S. Navy (hydrographic surveys)
1946–56	U. S. Geological Survey (rare earth deposits)—part time
1950–56	California Institute of Technology (instructor, assistant professor)
1956–	The Ohio Oil Company (geological research)

Publications

Stratigraphy, structural geology, petrology

Professional Affiliations

American Association of Petroleum Geologists, member
American Institute of Mining, Metallurgical and Petroleum Engineers, member
Geological Society of America, fellow

S.E.P.M. Activity (Member, '55)

1959	Leader, Field Conference, Permian Basin Section SEPM
1961–62	Secretary-Treasurer

NOMINEES FOR S.E.P.M. COUNCILOR (PALEONTOLOGY)
1962–1963

WILLIAM H. EASTON

Professor of Geology, University of Southern California, Los Angeles, California
Born, January 14, 1916, Bedford, Indiana

Academic Training

George Washington University, B.S., '37; M.A., '38
University of Chicago, Ph.D., '40

Experience

1940–44 Illinois Geological Survey (geologist)
1944–46 U. S. Navy Reserve
1946– University of Southern California (professor)

Publications

Carboniferous stratigraphy, paleontology, oil and gas resources and exploration, invertebrate paleontology

Professional Affiliations

American Association of Petroleum Geologists, member
Geological Society of America, fellow
Paleontological Society, member
Sigma Xi

S.E.P.M. Activity (Member, '41)

1955–56 President Pacific Section SEPM

ALAN B. SHAW

Consulting Geologist, Wheat Ridge, Colorado
Born, March 28, 1922, Englewood, New Jersey

Academic Training

Harvard University, B.A., '46; M.A., '49; Ph.D., '49

Experience

1949–55 University of Wyoming (assistant professor)
1955–60 Shell Oil Company (paleontologist)
1960– Consultant

Publications

Paleozoic paleontology, stratigraphy

Professional Affiliations

American Association of Petroleum Geologists, member
Geological Society of America, fellow
Paleontological Society, member
Palaeontographical Society, member
Sigma Xi

S.E.P.M. Activity (Member, '56)

1959– Associate Editor, Journal of Paleontology

NOMINEES FOR S.E.P.M. COUNCILOR (MINERALOGY)
1962–1963

RALPH W. EDIE

Consulting Geologist, Andrichuk and Edie, Calgary, Alberta, Canada
Born, October 2, 1921, Smoky Lake, Alberta, Canada

Academic Training

University of Alberta, B.Sc., '45; M.Sc., '49
Massachusetts Institute of Technology, Ph.D., '52

Experience

1948–50	Eldorado Mining and Refining, field geologist
1952–53	Texaco Exploration Company, research geologist
1953–55	Shell Oil Company, research geologist
1955–56	Alex McCoy and Associates, petroleum geologist
1956–	Consultant

Publications

Petrology, sedimentation

Professional Affiliations

American Association of Petroleum Geologists, member
Geological Society of America
Geological Association of Canada
Canadian Institute Mining and Metallurgy
Canadian Well Logging Society
Canadian Society of Exploration Geophysicists

S.E.P.M. Activity (Member, '58)

THEODORE R. WALKER

Associate Professor of Geology, University of Colorado, Boulder, Colorado
Born, February 8, 1921, Madison, Wisconsin

Academic Training

University of Wisconsin, Ph.B., '47; Ph.D., '52

Experience

1952–53	Illinois Geological Survey (assistant geologist)
1953–	University of Colorado (assistant professor, associate professor)

Publications

Sedimentary petrology, sedimentation, ground-water geology

Professional Affiliations

American Association of Petroleum Geologists, member
Geological Society of America, fellow
American Association for the Advancement of Science, member
Sigma Xi

S.E.P.M. Activity (Member, '55)

1959	Membership Committee
1961	Co-Chairman, Technical Program SEPM Denver Meeting
1961	Associate Editor, Journal of Sedimentary Petrology

JACK L. HOUGH—(*Continued from page 904*)

Professional Affiliations

American Association of Petroleum Geologists, member
Geological Society of America, fellow
American Association for the Advancement of Science, fellow
American Society of Limnology and Oceanography, member
American Geophysical Union, member
Sigma Xi

S.E.P.M. Activity (Member, '32)

1949–61 Editor, Journal of Sedimentary Petrology
1961–62 Chairman, Publications Committee

NEW OFFICERS, PERMIAN BASIN SECTION

The Permian Basin Section of the S.E.P.M. has elected new officers, their one-year term beginning April, 1961. They are as follows:

President: W. ELLIS HALL, Atlantic Refining Company, Midland, Texas
First Vice-President: RICHARD D. JONS, c/o Ralph Lowe, Midland, Texas
Second Vice-President: LEO HENDRICKS, Texas Christian University, Fort Worth, Texas
Secretary: KENNETH R. ETTER, Phillips Petroleum Company, Midland, Texas
Treasurer: DAVID S. HOLLAND, Ohio Oil Company, Midland, Texas
Past-President: GARNER L. WILDE, Humble Oil & Refining Company, Midland, Texas

NOTICE OF PAGE CHARGE AUTHORIZATION

The editors wish to call to the attention of prospective authors a ruling by the S.E.P.M. council authorizing the application of page charges to articles offered for publication in the *Journal of Paleontology*. Application of the charges is left to the judgment of the editors and will be applied at the rate of $20.00 per page.

Charges will be applied to manuscripts considered excessive in length or of a nature requiring special treatment. In addition, authors of articles that have been supported by grants that include funds for publication costs, or whose organizations are in a position to pay page charges, will be asked to subsidize publication of their articles to the degree that their funds allow. Authors are further urged to include allowances for publication costs in any future grant proposals.

Inability to pay assessed charges will in no way prejudice publication of an article, but authors are reminded that publication delays of prohibitive length lie in the near future if the size of the *Journal* cannot be increased through subsidies.

M. L. THOMPSON
CHARLES COLLINSON, *Editors*

BEST PAPER AWARD, 1961 S.E.P.M. MEETING

The Best Paper Award Committee listened to and observed all fifty-nine papers presented at the Society's 1961 annual meeting at Denver. After considering the offerings on the basis of content, organization, presentation, and quality of illustrations, the committee selected the paper "Classification of modern Bahamian carbonate sediments," by John Imbrie and E. G. Purdy, as the award-winning paper for 1961. Both authors are to be congratulated and Imbrie, as the deliverer of the oral presentation, will receive a certificate of award at the next annual meeting.

In addition to this award, the committee has recommended that the following three papers be recognized for their outstanding qualities and receive "honorable mention:"

John C. Ferm and E. G. Williams—Kittanning paleography in western Pennsylvania
Albert L. Kidwell—The effect of wind-driven water movement on sediment distribution, Gulf of Batabano, Cuba

Louis S. Kornicker and Donald W. Boyd —The Alacran reef complex of the Campeche bank

To Imbrie and Purdy, as well as to the authors of the "honorable mention" presentations, the committee extends its congratulations and thanks for their contributions to a highly successful program.

ROGER L. BATTEN
WILLIAM B. N. BERRY
JOHN B. DROSTE
RICHARD L. JODRY
CHARLES H. SUMMERSON
FREDERICK W. CROPP, *Chairman*
Best Paper Award Committee

MICROCARD EDITION OF JOURNAL

The Microcard edition of the *Journal of Paleontology*, Volumes 1–30, is now available at a price of $210.00 from J. S. Canner & Company, Inc., Boston, Roxbury 20, Massachusetts. Single volumes can also be supplied at various prices depending on the number of cards involved.

OFFICERS GULF COAST SECTION, S.E.P.M.

President: CLAUDE M. QUIGLEY, JR., Houston, Texas
Vice-President: HAROLD V. ANDERSEN, Baton Rouge, Louisiana
Secretary: E. ANN BUTLER, Baton Rouge, Louisiana
Treasurer: EDWARD MARKS, Houston, Texas

PALÄONTOLOGISCHE GESELLSCHAFT AND DEUTSCHE GEOLOGISCHE GESELLSCHAFT MEETINGS

Dates for the 1961 conventions of the Paläontologische Gesellschaft and the Deutsche Geologische Gesellschaft which will be held in Hamburg in August and September are as follows:

PALÄONTOLOGISCHE GESELLSCHAFT

Preconvention field trip	August 25
Lecture sessions	August 26–29
Postconvention field trip (jointly with D. G. G.)	August 30–31

DEUTSCHE GEOLOGISCHE GESELLSCHAFT

Preconvention field trip (jointly with P. G.)	August 30–31
Lecture sessions	September 1–4
Postconvention field trip	September 5–9

Main Theme—Geology of the deep subsurface of the North German flatland and adjoining territory.

Presiding officer for both sessions—Professor Dr. E. Voigt, Hamburg 13, Von-Melle-Park 11, Geologisches Staatsinstitut.

McLEAN PALEONTOLOGICAL LABORATORY

James D. McLean, Jr., Box 916, Alexandria, Virginia, U.S.A.

Card catalogues of fossils available by subscription, created on contract or by mutual agreement. Compilation and research facilities by contract. Training program for micropaleontologists offered.

NOW

available

•

SPECIAL PUBLICATION NO. 8:

Index, Journal of Paleontology,

Volumes 1-25, 1927-1951

In two parts, subject-author and genus-species, bound in one volume. Pp. 3-364. Price, $8.00 ($6.50 to members of S.E.P.M., P.S. and A.A.P.G.).

•

SPECIAL PUBLICATION NO. 9:

Taxonomic Notes

on the Species Figured by H. B. Brady in his Report on the Foraminifera Dredged by H.M.S. *Challenger* During the Years 1873-1876

Containing reproductions of Brady's 115 plates. Pp. vii-xxiv and 2-238. Price, $8.50 ($7.00 to members of S.E.P.M., P.S. and A.A.P.G.).

•

order from and make checks payable to

THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

Box 979, Tulsa 1, Oklahoma

NOMENCLATURAL NOTE

Authorship of gastropod genus *Aspidotheca* ..... *Curt Teichert* 880

REVIEW

Ecology and distribution of Recent Foraminifera, by Fred B. Phleger ..... *Alfred R. Loeblich, Jr.* 882

SOCIETY RECORDS AND ACTIVITIES

Reports and minutes of the thirty-fifth annual meeting of the S.E.P.M. 884

S.E.P.M. nominees for office, 1962-1963 904

New officers, Permian Basin Section, S.E.P.M. 909

Notice of page charge authorization 909

Best paper award, 1961 S.E.P.M. Denver meeting 909

New officers, Gulf Coast Section, S.E.P.M. 910

Ex-British Government GEOLOGICAL INSTRUMENTS, ETC.

LIQUID PRISMATIC COMPASS

(SERVICE PATTERN MARK III)

Precision pocket instrument engraved 0-360° in one degree divisions. The mother-of-pearl dial is suspended in non-freezing liquid. Adjustable magnifying prism. Well-made hinged case of 2 in. diameter. Net Weight 11 oz. Current cost approx. $36.40.

With Web Case.
Post and Packing 50 cents **$11**

SIGHTING PLANE TABLE ALIDADES

An extremely well-made instrument constructed of Phosphor Bronze fitted with sighting vanes and parallel rule attachment. Length 18 in. Net weight 2¼ lb. In polished wood container, all in new condition. Fraction of cost.
Post and Packing $1.75 **$5**

EX-M.O.S. SURVEYING RANGEFINDERS

Coincidence type. Base 80 cm. Range 250-10,000 yards. Good serviceable condition. Current cost approx. $420.08. Short or tall tripod can be supplied as an extra.
Freight Forward **$34**

INDIAN CLINOMETERS

Base 0½ in. Ministry release at fraction of cost. New and unused. With Leather Case. Post and Packing $1.75 **$10.50**

ANY ITEM ON
14 DAYS' APPROVAL

Ex-Govt. 6 x 30 Prismatic Binoculars by Taylor Hobson. Guaranteed 5 years. With waterproof web pouch. $21.70
Post & Packing $1.60

CHARLES FRANK LTD.

67-75 SALTMARKET,
GLASGOW, C.1.
SCOTLAND

ESTABLISHED 1907 *SEND FOR ILLUSTRATED CATALOGUE*